A HEYWOOD PUBLICATION

British Chemical Engineering

THE JOURNAL DEVOTED TO THE TECHNIQUES OF CHEMICAL ENGINEERING APPLIED TO INDUSTRY

The main articles in this month's issue of* British Chemical Engineering *are devoted to Process Instrumentation, and we have pleasure in presenting an introductory message to this special issue from Mr. L. A. Woodhead, President of the Scientific Instrument Manufacturers' Association.

FEBRUARY 1960
Vol. 5 No. 2

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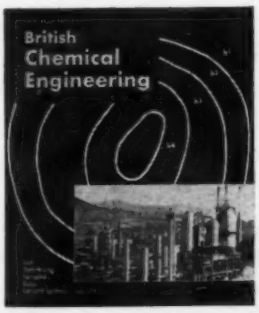

A general view of plant at the British Petroleum Co.'s Llandarcy oil refinery is inset into a graphical representation of the functional relationship, for two control variables, of an equation defining the response of a system as discussed in the article by N. W. Rees on page 106.

Classified Advertisements, after page 84

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Résumés

B.C.E., 5, 2, 88. U.D.C. No. 66.02-52

REGULATEUR OPTIMISANT POUR LES INDUSTRIES DE TRAITEMENT CHIMIQUE

par D. Archer

Un computateur logique pour les emplois spéciaux a été construit pour l'opération des installations de traitement chimique. Un, deux ou plusieurs variables d'entrée characterisant le processus (qui peuvent varier indépendamment) sont pre-sélectionnés par ce regulateur ; celui-ci agit sur ces variables periodiquement dans le but d'atteindre les valeurs optimaux, maximaux ou minimaux pour une des valeurs d'issu ou une fonction de celles-ci.

B.C.E., 5, 2, 95. U.D.C. No. 66.048.34-52

RÉGULATION AUTOMATIQUE DES COLONNES DE RECTIFICATION

par N. J. Hassett

L'auteur décrit en bref les bases de la théorie de régulation automatique et démontre comment le système de régulation le plus favorable pour une colonne de rectification peut etre determiné. Les réponses nécessaires pour les instruments et régulateurs individuels sont aussi indiqués.

B.C.E., 5, 2, 99. U.D.C. No. 66.012.1: 66.012-52: 657.47

EVALUATION DES COÛTS D'INSTRUMENTATION ET D'APPAREILLAGE DE RÉGULATION AUTOMATIQUE

par M. Stogens

Cinq méthodes pour l'évaluation des coûts d'instrumentation et de l'appareillage de régulation automatique sont décrites. Une connaissance du système de régulation à employer dans l'installation et des prix des éléments individuels du système de régulation est nécessaire pour le choix de la méthode la plus précise. Il faut tenir compte des coûts d'installation et des coûts indirects.

B.C.E., 5, 2, 103. U.D.C. No. 681.121.8: 66-498.4

MESURE DE L'ÉCOULEMENT D'UN LIQUIDE À HAUTE TEMPÉRATURE À L'AIDE D'UN COMPTEUR VENTURI

par R. C. Cairns et P. Fisher

Les auteurs décrivent le développement d'une méthode pour la mesure de la charge differentielle produite par le sodium liquide a 750° F s'écoulant à travers un compteur Venturi. L'appareillage permet les calibrages individuels en place aux dispositifs de transmission de charge employés.

B.C.E., 5, 2, 106. U.D.C. No. 621-503.5: 66.02-52: 681.141

SYSTÈMES DE RÉGULATION À ADAPTION AUTOMATIQUE

par N. W. Rees

La caracteristique principale de ces systèmes est le fait que la machine " note " la réponse á une action de régulation et puis effectue une autre action. Ce processus se répète jusqu'à l'obtention de la réponse cherchée.

Kurzreferate

B.C.E., 5, 2, 88. U.D.C. No. 66.02-52

EINE OPTIMISIERREGLUNG FÜR DIE CHEMIEVERFAHRENSINDUSTRIEN

von D. Archer

Ein logischer Rechner für Sonderzwecke ist für den Betrieb von Chemieverfahrensapparaten hergestellt worden. Diese Reglung optimisiert ein Verfahren, indem sie Fixpunkte für zwei, drei oder mehrere unabhängig veränderliche Mengen von Eingangsmaterial bietet. Diese Fixpunktwerte werden periodisch verstellt, um eine Optimal-, Maximal- oder Minimalausgangsveränderliche oder eine Funktion von Ausgangsmengenveränderlichen zu geben.

B.C.E., 5, 2, 95. U.D.C. No. 66.048.34-52

AUTOMATISCHE REGLUNG VON FRAKTIONIERKOLONNEN

von N. J. Hassett

Verfasser gibt eine kurze Übersicht der Grundlagen der Selbstreglungstheorie und zeigt, wie das günstigste Reglungssystem für eine Distillerkolonne festgelegt werden kann, sowie das erforderliche Ansprechen für einzelne Instrumente und Regler.

B.C.E., 5, 2, 99. U.D.C. No. 66.012.1: 66.012-52: 657.47

DIE KOSTENSCHÄTZUNG VON VERFAHRENSINSTRUMENTEN UND SELBSTREGLUNGSAPPARATEN

von M. Stogens

Fünf Methoden für die Kostenschätzung von Instrumentierung und Selbstreglungsapparaten werden besprochen. Die genaueste Methode erfordert eine Kenntnis des anzuwendenen Verfahrensreglungssystems sowie die Kosten von einzelnen Elementen der Reglungssysteme. Es ist wichtig, die Einbau- und indirekten Kosten in Betracht zu ziehen.

B.C.E., 5, 2, 103. U.D.C. No. 681.121.8: 66-498.4

STRÖMUNGSMESSUNG EINER HOCHTEMPERATURFLÜSSIGKEIT MIT EINEM VENTURIMESSER

von R. C. Cairns und P. Fisher

Die Entwicklung einer Methode zur Messung des von geschmolzenem, bei 750° F durch ein Venturimesser fliessendem Natrium erzeugten Differenzialdrucks wird beschreiben. Die Apparatur erlaubt, einzelne Eichungen an den Druckübertragungsvorrichtungen an Ort und Stelle durchzuführen.

B.C.E., 5, 2, 106. U.D.C. No. 621-503.5: 66.02-52: 681.141

SELBSTEINSTELLENDE REGLUNGSSYSTEME

von N. W. Rees

Das charakteristische Merkmal dieser Systeme ist, dass die Maschine das Ansprechen auf eine Reglungseinwirkung "aufzeichnet" und dann eine weitere Einwirkung ausführt. Dieser Prozess wiederholt sich, bis das erwünschte Ansprechen erreicht ist.

Резюме

B.C.E., 5, 2, 88. U.D.C. No. 66.02-52

ОПТИМИЗИРУЮЩИЙ КОНТРОЛЬ ДЛЯ ПРОМЫШЛЕННОСТЕЙ ХИМИЧЕСКОЙ ОБРАБОТКИ

Д. Арчер

Разработана вычислительная машина, выполняющая логические операции для специальных целей при эксплоатации химических аппаратов. Контроль достигает оптимум процесса путем обеспечения заданных значений для двух, трех или более независимых переменных количеств входного материала. Контроль периодически регулирует эти величины заданных значений с тем, чтобы достичь оптимум, максимум или минимум переменной выходного процесса или функции переменных выходного процесса.

B.C.E., 5, 2, 95. U.D.C. No. 66.048.34-52

АВТОМАТИЧЕСКОЕ РЕГУЛИРОВАНИЕ РЕКТИФИКАЦИОННЫХ КОЛОНН

Н. Дж. Хэссетт

Автор дает короткий обзор основ теории автоматического регулирования и показывает возможность определения оптимальной регуляционной системы для ректификационных колонн, а также необходимых ответных характеристик отдельных приборов и регуляторов.

B.C.E., 5, 2, 99. U.D.C. No. 66.012.1: 66.012-52: 657.47

ОЦЕНКА СТОИМОСТИ ПРИБОРНОГО ОБОРУДОВАНИЯ И АВТОМАТИЧЕСКИХ РЕГУЛЯЦИОННЫХ АППАРАТОВ

М. Стогенс

В статье описано пять способов для оценки стоимости приборного оборудования и автоматических регуляционных аппаратов. Выбор наиточнейшего метода требует знания производственной контрольно-измерительной системы, которая будет применена в установке, а также цен отдельных элементов регуляционных систем. Необходимо принять в расчет монтажные и косвенные затраты

B.C.E., 5, 2, 103. U.D.C. No. 681.121.8: 66-498.4

ИЗМЕРЕНИЕ ПОТОКА ВЫСОКОТЕМПЕРАТУРНОЙ ЖИДКОСТИ ВЕНТУРИ МЕТРОМ

Р. Ч. Кэрнс и П. Фишер

В статье описана разработка способа для измерения дифференциального напора, создаваемого расплавленным натрием, текущим через Вентури метр при 750° ф. Оборудование позволяет производить отдельные эталонирования приборов для передачи давления на месте работы.

B.C.E., 5, 2, 106. U.D.C. No. 621-503.5: 66.02-52: 681.141

САМОУСТАНАВЛИВАЮЩИЕСЯ РЕГУЛЯЦИОННЫЕ СИСТЕМЫ

Н. У. Рис

Особенностью таких систем является то, что машина «отмечает» ответ на регулирующее воздействие, а затем осуществляет дополнительное воздействие. Процесс повторяется до получения нескольких ответа.

DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Educating Engineers in Control Systems Design

CONTROL technology in always concerned with design, construction and operation of relatively large and complex systems subjected to changing loads and/or requirements. Thus, the unifying central theme is dynamics regardless of the nature of the elements constituting the system. In his James Clayton Lecture to the Institution of Mechanical Engineers, DR. JOHN A. HRONES outlined briefly the history of automatic control and more extensively its basic concepts. In assessing current research, he pointed to the new trends in self-adaptive and sampled-data systems—incidentally we carry an article on this theme in the present issue, page 106—and to statistical work on systems subject to random inputs.

DR. HRONES, who is vice-president for Academic Affairs, Case Institute of Technology, concluded by explaining some of the movements in engineering education in the United States. Research and design activities in the field of control systems have led to the establishment of interdepartmental college laboratories attracting staff and students from mechanical engineering, electrical engineering, from the management school and from mathematics. Programmes of graduate study have been directed towards providing the breadth of knowledge that is essential to frontier work in control systems design. This movement at the graduate level has its counterpart in the undergraduate engineering training. Serious consideration is being given to programmes in which the first three or more years are essentially the same for all engineering students with great emphasis on work in the basic sciences, in mathematics, and in the humanities and social studies. There will be an integrated programme of study in materials. Students will be encouraged to develop analytic skills but there will also be a continuous stream of design throughout the entire programme. The new trends require a continuing alertness to the rapidly occurring developments in science and technology and a willingness to move swiftly to make changes in the educational and professional structure.

Guard Your Mixers Effectively

AN old experienced foreman once advised us that unguarded machinery was safer than that with an imperfect guard. We were reminded of this adage by an account in *Accidents* (No. 41) of an operator's fall into a mixer. The trough—6 ft. long by approximately 2 ft. 6 in. square—was installed so that the upper rim was about 5 ft. above the ground. A wooden cover constructed of new 1 in. timber boards running lengthwise and joined together by 1 in. cross-battens rested on a 2 in. wide flange running all round the inside rim of the trough and had a feed opening about 1 ft. square. A man stood on this cover to empty a bag into the opening. Unknown to him, however, the cover had become displaced so that one end had come off its supporting flange. The weight of the man and bag of material caused the front board to split along the grain throughout its length. Both cover and man fell into the trough. Fortunately, the cover became jammed between the revolving blades and the trough, causing the motor to stall thus averting serious injury to the man. After the accident a new cover was fitted, hinged to the trough to prevent displacement. It was constructed of boards set crosswise and fitted with an interlocking switch.

Covers of trough-type mixers are usually made in the form of a metal grid supported by a robust frame hinged to the machine. Alternatively, if it is necessary to suppress the escape of dust, the cover should be made of sheet metal secured to a suitable frame. If necessary a feed opening can be incorporated fitted with a sliding panel. The factory inspectors point out that an opening of this type must have a grid to prevent the operator's hand reaching the blades. Under Section 14 of the 1937 Factories Act there is a general requirement that all dangerous machines should be fenced, but in addition the inspectorate has specifically made recommendations in an earlier issue of the same journal (Vol. 26, Item 13) for the protection of this type of machine including a table of measurements for the spacing of grid bars. They also comment that it is not good practice to stand on the covers of such machines. A loading platform alongside should be provided if the feeding cannot be done from the floor or by mechanical means.

Cleaning at High Pitch

ON the laboratory scale and in instruments, ultrasonics now find many applications but it is rare to hear of successful full-scale direct industrial use. Ultrasonic techniques have been tried out for speeding up pickling, emulsifying and other processes but success has been achieved only in isolated cases. However in developing the prototype for the next generation of nuclear power stations it was considered that the gilled heat exchanger must be cleaned to a standard quite unusual for heavy industrial plant of this kind. Use of ultrasonics proved to be the only practical method for achieving it. According to *Dawe Digest* (Vol. 2, No. 4) a plant has therefore been put into service at the Derby works of International Combustion Ltd.

The heat exchanger elements consist of 2 in. diameter tubes of special steel with a $\frac{1}{2}$ in. deep spiral gill of 18-gauge steel at a pitch of six to the inch. The cleaning sequence finally prescribed by the Atomic Energy Authority consisted of pickling in a citric acid solution, followed by a rinse, then a dilute acid wash followed by another rinse, and finally ultrasonic cleaning with trichlorrethylene as the agent. A 1500 gallon tank is needed to accommodate the largest elements, which weigh about two tons. Exhaust fans remove the vapour through ducts round the inner edge of the tank. Two ultrasonic generators are used. Each is of 4kW peak output and drives seven stainless-steel cased transducers mounted in a separate trough. This trough runs on a trolley which is advanced

step by step, to act on one section of heat exchanger element at a time, each pair of adjacent tubes being separated by a steel baffle plate designed to localise the ultrasonic energy. Each section of the element is subjected to five minutes' cleaning. The displaced matter is held in suspension and not redeposited on the element when it is removed from the bath.

Mixing or Cutting?

AT the Road Research Laboratory a problem has arisen which provides a surprising link between mixing and metal-cutting techniques. In the mix-in-place method of constructing stabilised-soil bases the pulverisation of the soil *in situ* precedes mixing with the stabiliser. With clay soils considerable power is required to operate the rotor of the machine, mainly to achieve pulverisation, and this limits the use of the mix-in-place method on the heavier clay soils. To assist in the design of improved machines a study has been begun of the effect of rotor design, speed and direction of rotation on the degree of pulverisation produced and the power consumed when working with these soils. In *Road Research* 1958 (H.M.S.O., 1959, 5s. 6d.) it is stated that a building has been erected containing a test bed approximately 90 ft long and 30 ft wide filled with the soil to a depth of about 18 in. so that the investigation can be made under controlled conditions.

We now understand that this has proved to be in essence a machining problem similar to that involved in working on a lathe. The edge of the cutter on the rotor is readily blunted by the clay so that it is necessary to design a cutting edge backed off. Efforts are being directed to produce a good chip which will break away cleanly.

New Collecting Plates for Electroprecipitators

THE collecting plate of an electrostatic precipitator is probably its most important component. A satisfactory collecting plate must satisfy a number of conditions; it must, for example, have a high resistance to the formation of back corona, that is, the localised discharge which occurs when the surface of the plate is covered with a layer of poorly conducting dust; and it must also maintain a high voltage level. A design of plate which allows even a small increase in energisation level through either a change in strength of or distribution of the electric field, will improve the collecting efficiency considerably. The plate has also to satisfy aerodynamic conditions. For example, the dust laden gas passing through the precipitator must be uniformly distributed between the plates and a protected area must be provided to allow the dust to fall under gravity to the collecting hopper, immediately after the plates have been rapped. This protected area is provided by the use of baffles, which must also ensure that the collected dust is not re-entrained. Certain mechanical requirements also have to be satisfied. Thus the plate must be rigid and resistant to permanent deformation, and yet be light enough for easy handling. One badly bowed plate in an assembly of a hundred or so other plates will reduce the applied voltage so that arresting ability will suffer.

A series of tests* have been carried out upon three varieties of collecting plate; one of the perforated type, one in expanding metal and the third of sheet metal. The sheet plate was able to accept a corona current at least twice that of the perforated and expanded metal types before back corona set in. It was superior to the other types aerodynamically and the triangular baffles employed were able to provide a reduced-velocity reversed-direction flow at the plate surface. This feature greatly improves the chance of recapturing an eroded particle and it also provides the shielded area for the dust released on rapping. Triangular baffles were shown to give the most stable low velocity area along the plate surface and the exact dimensions of the baffles were not of much importance. Nevertheless, the triangular form was shown to be superior to other geometries, for flat projections in particular make poor baffles. Mechanically too the flat plate was shown to have considerable advantages over the other types and was virtually free from the risk of permanent deformation, which cannot be said of the other types. The plate collector also proved to have the best rappability on account of its greater rigidity.

The plate form of construction is also more economical since its first cost is two-thirds of that of the other types. Already the new type of plate has undergone field trials in the U.S.A. and is installed in electroprecipitators at some 50 plants, treating more than 25 million cu. ft. of gas per minute. Among the applications are a cement kiln, a paper mill, an oxygen converter and an open hearth furnace. Some of the materials being collected by precipitators fitted with the new plate include powdered catalysts, gypsum and alumina dusts.

* Paper No. 59-A-259 presented by H. J. White and W. A. Baxter Jnr. to the ASME Annual Meeting Atlantic City, 1959.

Which Metals Resist Fuming Nitric Acid?

INDUSTRIAL and military uses are both contributing to the increased importance of fuming nitric acid of 98 to 99% concentration. At this level of concentration there is little ionisation so that the acid character is not very marked but the material is strongly oxidising. The head of laboratory at the French Société d'Etude de la Propulsion par Réaction has now published* experimental results indicating the corrosive effects on three chromium/nickel alloys and 19 stainless steels. Of these, two were martensitic, two ferritic and the remainder austenitic. Composition of the test acid was as follows:

HNO_3 not less than 98.5%
N_2O_4 not greater than 0.5%
$Al_2O_3 + Fe_2O_3$ not greater than 0.01%
H_2SO_4 not greater than 0.05%

Most of the alloys were found to have excellent resistance to the cold acid. In the boiling acid, however, corrosion rates were generally about one hundred to two hundred times those at ordinary temperatures. Adequate resistance was shown by the 18-10 alloys with low carbon content with or without addition of molybdenum, tungsten or copper. In these cases corrosion was only superficial and resistance was not weakened by welding.

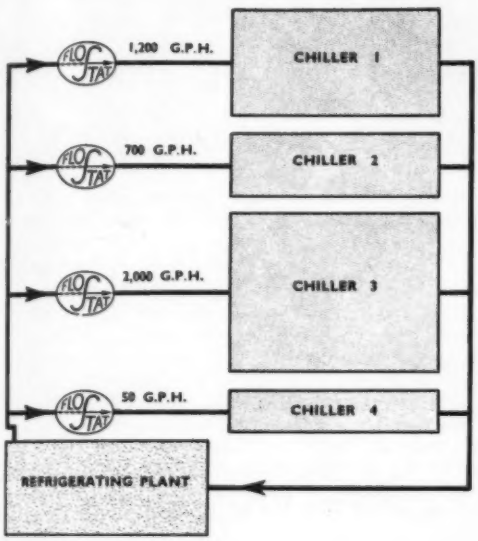
* Michel L.-J. Bernard, *Corrosion et Anti-Corrosion*, 1959, Vol. 7, No. 11, p. 373

The Growth of Crystals

CRYSTALLISATION has been claimed as the first physico-chemical separation ever used by man. Yet we continue to hear of new developments of old processes based on it—for example freezing out fresh water from sea water—as well as totally new adaptations. Are we approaching the time when we can transcend empirical methods in controlling the way crystals grow? In recent years there has been extensive work in this field, particularly related to the manufacture of electronic devices, which has included considerable attention to fundamentals. A recent review by W. DEKEYSER in *Industrie Chimique*

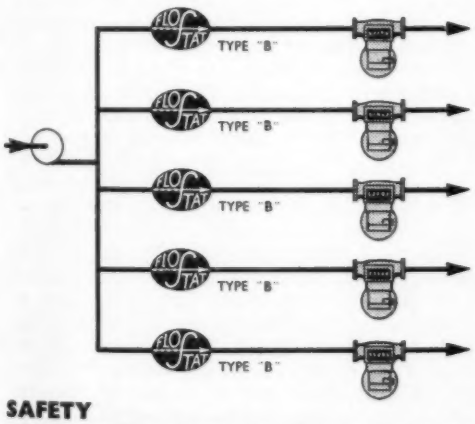
SELF-ACTING FLOW CONTROLLERS

A WIDE RANGE OF INEXPENSIVE STANDARD CONTROLLERS BRINGS THE ADVANTAGES OF AUTOMATION TO MANY INDUSTRIAL PROCESSES



DISTRIBUTION

TOTAL OUTPUT OF PLANT UNIT DIVIDED IN PROPER PROPORTIONS TO ANY NUMBER OF CONSUMER POINTS. AS MANY AS 100 FLOSTATS HAVE BEEN USED ON A SINGLE SITE AS ILLUSTRATED.



SAFETY

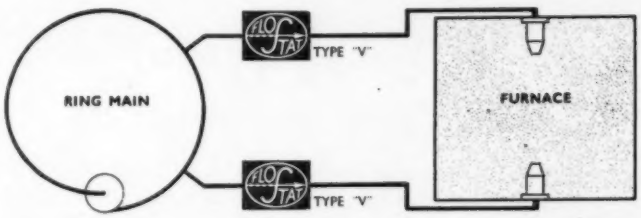
THE BULK METERS AT AN OIL TERMINAL WOULD BE DAMAGED BY EXCESS FLOW IF LESS THAN HALF THE LOADING BRANCHES WERE IN USE AT ANY MOMENT. FLOSTATS TYPE 'B' ECONOMICALLY PROTECT THE METERS BY LIMITING THE FLOW, WHILST NORMALLY CAUSING NEGLIGIBLE RESISTANCE.

G. A. PLATON LTD.
323a WHITEHORSE ROAD
CROYDON SURREY
THOrnton Heath 1631

The Flostat self-acting flow controller regulates the flow of liquids or gases to within 1% of the desired rate, irrespective of variations in pressure either upstream or downstream from the installation. It is simple, robust, reliable and needs no attention in service.

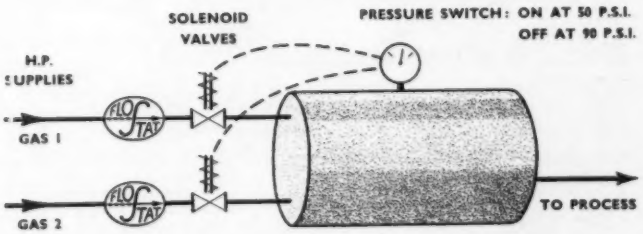
The types of Flostat now readily available are:—The Standard Flostat which is factory set to user's specification; the Type 'V' Flostat which is fitted with a calibrated control giving a 10:1 flow range; the Type 'B' Flostat which is a flow limiting device designed to provide the minimum restriction to normal flow.

The accompanying diagrams illustrate some of the many ways in which self-acting Flostats may be used to improve plant efficiency. The particular examples shown have been chosen to give some indication of the universal usefulness of Flostats throughout Industry.



BURNERS

FLOSTAT TYPE 'V' CALIBRATED FOR DESIRED FLOW RANGE (10:1 MAX.), MAINTAINS SELECTED FLOW CONTROL SETTING IN SPITE OF CHANGES IN RING MAIN PRESSURE OR BURNER BACK PRESSURE. IF FIRING ENDS ARE CHANGED, OVERSHOOT IS ELIMINATED.



BLENDING

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Belge, Vol. XXIV No. 11, p.1322, not only considers energy aspects of crystal growth but some of the discrepancies between theory and experimental results. Spiral growth occurs due to the filling of so-called Kossel sites—that is positions where a new cube can attach to three existing faces. Such sites can arise due to screw dislocation. Study of these spirals has helped considerably in elucidating a mechanism for crystal growth at low supersaturation of solutions. However the understanding of morphology also requires a satisfactory method of describing the kinetics of the growth of crystal faces and their interactions.

The State of the Nitrogen Industry

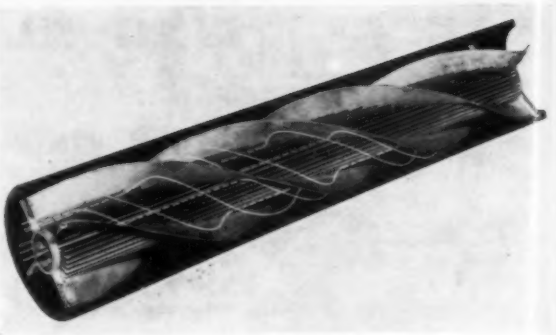
IT is one of the ironies of life that we can have a need for power alongside a coal crisis, a need for fertilisers while stocks in many countries are thought too high. The current issue of *Nitrogen* (No. 4, 1959) carries an annual report on the nitrogen industry by Aikman (London) Ltd. which provides some documentation on the latter issue. According to this both manufacture and use of nitrogen continued to increase in 1958/59. On a world scale, production was 9½% higher than in 1957/58 and consumption 7% higher. For Europe and Egypt alone the increases were greater—12% and 8% respectively. During 1959/60 it is estimated that these increases will continue; world production will rise by 6½% and use by 5% and the cumulative excess produced will be 5½%, taking into account results for earlier years.

In general the present stock position was thought by the authors to be satisfactory from the producers' point of view. Nevtheless this had evidently not been the view of producers and they had reduced prices to move their stocks. In addition, Japan's stock levels were thought excessive despite sales to Korea, India and elsewhere. The report gives a breakdown of the percentage figures in terms of actual tonnages for each relevant country or group. Tables set out production, consumption in industry and as fertilisers, exports and imports.

Elements of Improved Heat Transfer

NEEDS of nuclear reactors have been a constant spur in improving heat-exchange equipment and the latest *G.E.C. Atomic Energy Review* (Volume 2, No. 2) refers to two results of this stimulus. For advanced gas-cooled reactors fuelled with uranium dioxide oval-section tubes are being put forward for use as cross-flow elements. M. C. HARTNELL-BEAVIS reports that in comparison with longitudinal clusters at the same rating, channel output and temperature rise, the pressure drop is approximately halved at low ratings (10 MW/t), with an increasing advantage at higher ratings. No previous experimental data for banks of streamlined tubes in cross flow were found. Experiments were therefore designed to study the effects of varying the cross-sectional shape. Compared with the results for smooth round tubes it was discovered that at normal design Reynolds numbers (of over 10^6), the channel pressure losses, with the gas in cross-flow, drop by more than a factor of four on using the lenticular shape.

The Hunterston type of fuel element on the other hand is a polyzonal axial type, which has axial fins together with spiral flow separators or swirlers. In it the coolant follows the fins until it meets a spiral swirler, when it is deflected; it spirals along the channel wall, and returns to repeat the pattern between the fins. E. W. V. ACTON states that it has been found possible to correlate the experimental results for this type of can by empirical formulae, one referring to the Stanton number



and the other to the friction factor, both as a function of Reynolds number. In each case the property was assumed to be proportional to the function $(d_c)^A (d_f)^B (d_r)^C (n)^D (l)^E (t)^F (\phi)^G$, where d_c is channel diameter, d_f is the diameter over the fins of the can, d_r is the diameter over the root of the can, n is the number of fins, l is the swirler lead, t is the mean fin thickness, ϕ is the fin taper. Over ranges of Reynolds number suitable for use in design A, B, C, D, E, F, G are constants and values of indices were then found which gave the minimum standard deviation between calculated and observed values.

Displacement of Oil by Miscible Liquid

IF oil is recovered from reservoirs by displacing it with a miscible liquid, complete recovery can be achieved in the contacted area. Miscibility of the displacing and displaced phases eliminates the capillary forces which otherwise prevent full recovery. The process is called miscible fluid displacement. To cheapen it use has been made of a slug of miscible fluid followed by either gas or water.

At a symposium of the American Institute of Chemical Engineers, F. W. COLE and his colleagues—in Preprint 46—presented results of studies on radial cores of sandstone to determine the displacement efficiencies of various sizes of pentane slugs followed by a water drive, and the effects of varying free gas saturations on oil recovery by pentane displacement. One experimental core had a diameter of 9.6 in. and a second one, 18 in. Both were 2 in. thick. The cores were mounted in plastic, a small hole was drilled through the centre of each core to simulate an injection well, and provision was made to recover all fluids produced from the external boundaries. Results showed that there is usually an optimum slug size to inject ahead of a water flood. This optimum size will depend upon a number of economic factors which must be evaluated for each reservoir under study. In addition it was possible to recover more oil by air drive after completing the water flooding tests. W.E. BRIGHAM, *et el*, at the same symposium compared the rate of mixing between oil and a displacing liquid when using experimental glass bead packs (bead diameters 0.044 to 0.47 mm.) and natural cores. The latter caused much more mixing due to the inhomogeneity of reservoir rock. For this programme an oil/kerosene mixture was used as the displacing fluid in one set of runs. Trials using oils of approximately equal viscosity were also carried out—one of the oils being dyed red for convenience in identification and observation. Favourable conditions were those where the viscosity of the displacing oil was not lower than that of the oil displaced. A change as delicate as that from a ratio of 1.001 to 0.999 was detectable, producing a disproportionate increase in the dispersion rate. Details are in Preprint 44.

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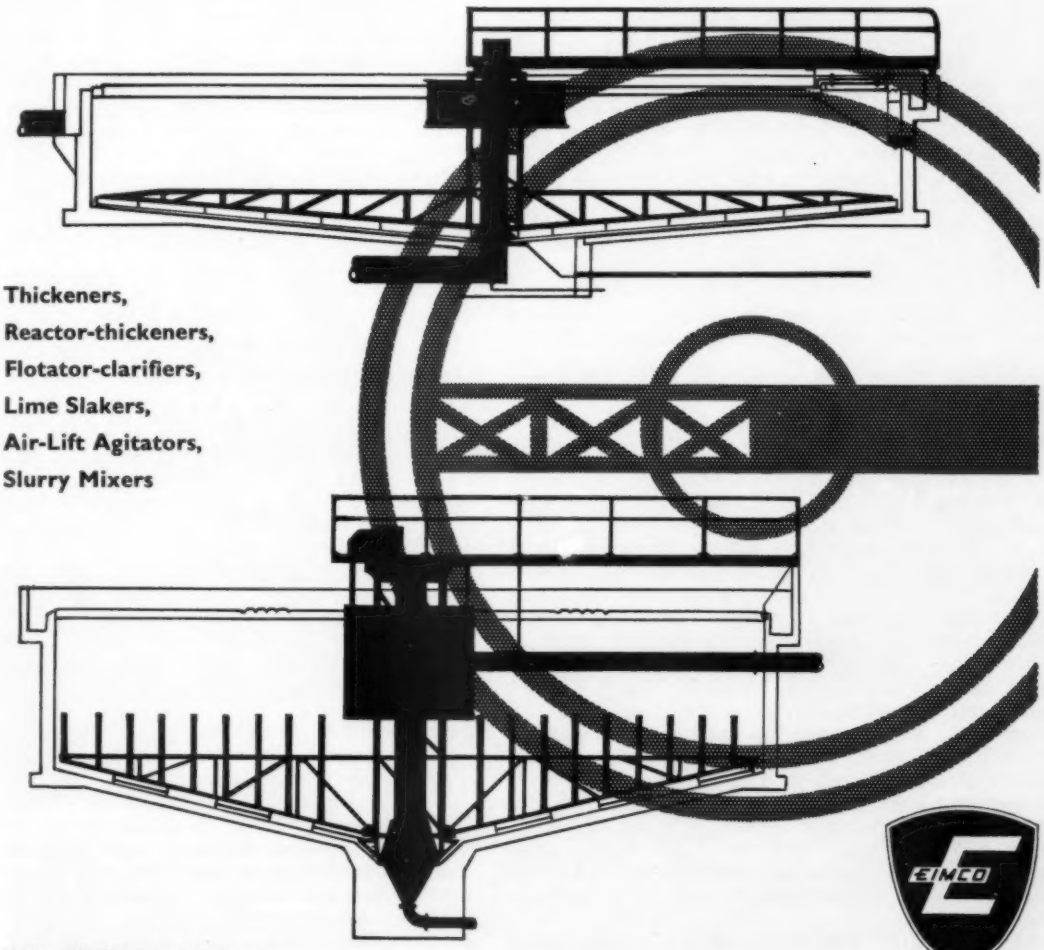

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P.2699

Calculating Multistage Separation by Digital Computer

ALTHOUGH based largely on examples dealing with distillation, a recent report* on multistage separation also considers liquid-liquid extraction. In it J. H. DUFFIN has illustrated various methods of attack by solving specific problems using both medium and large digital computers. After criticising the neglect of problem description in earlier treatments of the subject MR. DUFFIN has gone on to define the simple, general rule which governs what and how many variables are independent and must be set to define a separation problem. This is his formulation. Associated with any fractionation problem is a number of variables which describe the column and its operation. These variables are flows, temperatures, separation specifications, number of stages, column diameter, and in general, any quantity that satisfies the requirement of describing the column or its operation. Obviously, not all these variables are independent and can be arbitrarily set, and the number of independent ones changes with the column used and the operation performed. The direct rule is then as follows: "To completely describe the separation operation, a number of independent variables must be set equal to the number that can be set by construction or controlled by external means. Setting a lesser number in the problem description yields an infinitude of answers in solving for values of the remaining variables, whereas setting a greater number may lead to no answer."

After further discussion of this theme, there follows detailed treatment of mass-balance methods, energy-balance methods, calculations with variable other than bulk separation set and held, and calculations with complex columns. Later sections give examples for stripping and absorption columns and infinite mixture calculations.

* UCRL-8787 Chemistry—General. University of California, Lawrence Radiation Laboratory, Berkeley, California. Contract No. W-7405-eng-48. Available from Office of Technical Services U.S. Department of Commerce, Washington 25, D.C. $4.00.

Hydrogenation Catalysts on Silken Carriers

A LUSH combination of materials may surprisingly prove to be of value as a catalyst for hydrogenation reactions. It is prepared by co-ordinating palladous chloride with silk fibroin fibres and then hydrogenating the complex. The resulting silk-palladium has many assets to commend it as a general hydrogenation catalyst. It can also be used for asymmetric reduction of certain unsaturated compounds. A nylon-palladium catalyst similarly shows a high activity but does not give the same asymmetric effects. Catalysts of these types are particularly suitable for the preparation of saturated aldehydes and ketones from the corresponding unsaturated compounds. Aromatic C=C bonds are not attacked but aromatic carbonyl groups, or aldehyde, nitrile and nitro groups attached to aromatic rings are catalytically hydrogenated as are azobenzene and some oximino goups. There is also a weak catalytic effect for aliphatic nitro groups. After one run the activity of the silk-palladium catalyst is considerably increased and this higher activity persists for at least four more runs.

At Osaka University in Japan, extensive investigations of these materials have included attempts to determine the mechanism of the reactions and the form of the catalysts. According to the summary in *Platinum Metals Review* (January, 1960) it has been concluded that part of the palladium atoms are assembled in fine crystalline particles and the remainder probably becomes regularly arranged in the micelle structures of the fibres. There is a possibility, also, that certain regular structures emerge in the protein carrier itself.

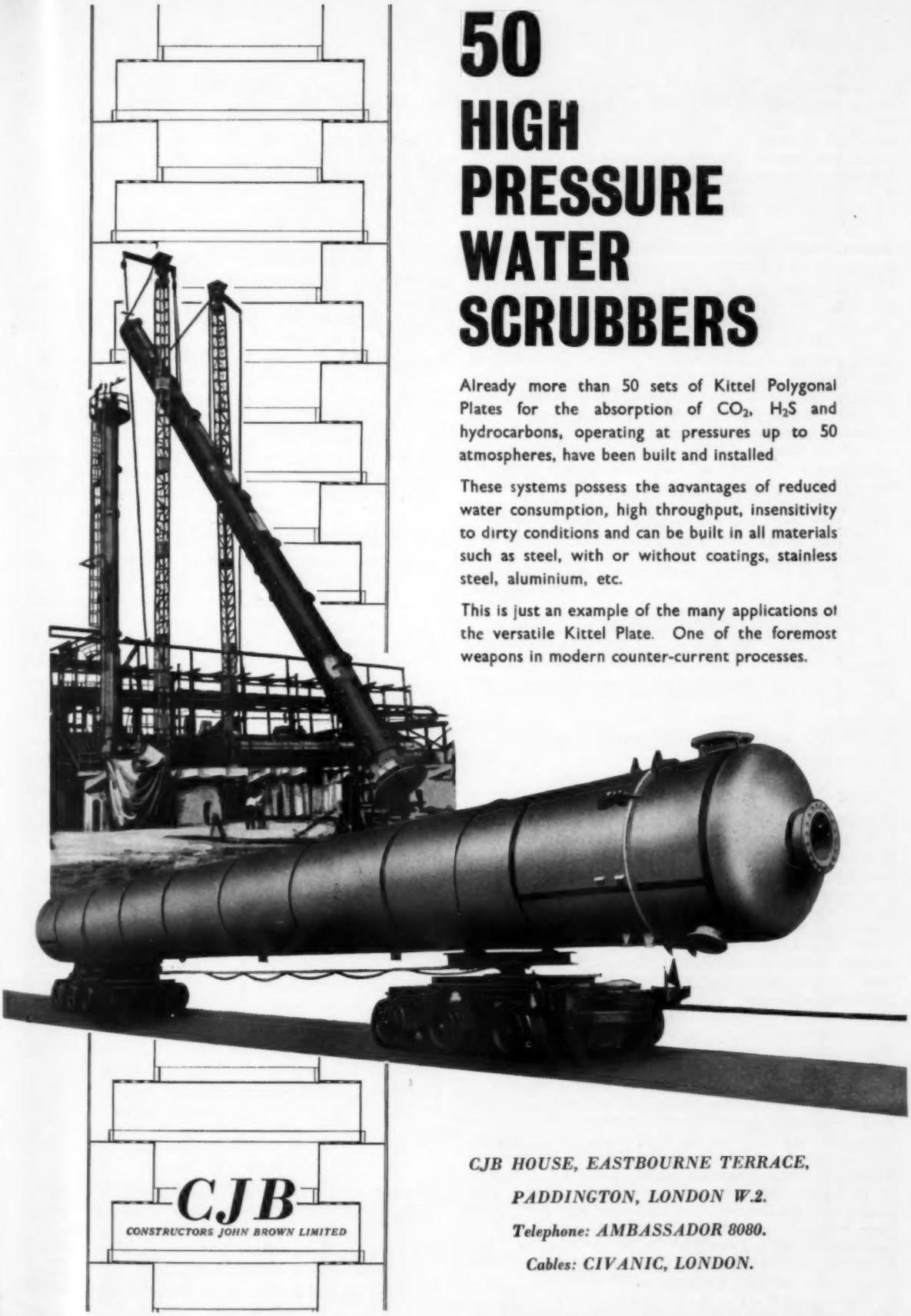
Heat Transfer Can Cause Turbulence at Low Re

EVEN at liquid flows with Reynolds Numbers of less than 700, it is possible to obtain a transition to turbulence in a vertical pipe if heat is being transferred thus causing natural convection effects. In the first place variations of the density and viscosity of the fluid cause a change from a parabolic velocity distribution. For the case of heating in upflow (or cooling in downflow) the fluid near the wall is accelerated relative to the fluid in the centre of the pipe due to the smaller density. This 'flattens' the velocity profile. If the temperature gradient is large enough a dimple develops in the centre of the velocity profile and sometimes flow is reversed. For cooling in upflow (or heating in downflow) density variation causes a deceleration of the fluid near the wall. With large enough temperature differences a reversal of flow can occur near the wall.

At an autumn conference of the Chemical Institute of Canada (Chemical Engineering Division), G. F. SCHEELE and colleagues reported a study of these phenomena using first a constant temperature wall and then a constant heat flux wall in the heat transfer section. Transition to turbulence was detected by the break up of a dye stream. Results showed two types of instabilities. For cooling in upflow, transition to turbulence is associated with the condition at which the velocity at the wall becomes zero. The instability develops rapidly in such cases. For heating in upflow it appears as if a length of pipe is required to allow the instabilities in the flow to grow. For a very long heat transfer section with constant flux heating, transition appears to be associated with the development of the dimple in the centre of the flow profile.

Electro-Hydraulic Crusher

THE background to a new process for particle size reduction is the production of metallurgical coke. It has been shown that the presence of a few per cent of chlorine in the coking charge reduces both the swelling power of the charge and the coking time without loss of quality of the coke. In this process the coal is halogenated in water and it is necessary for the coal to be very finely divided. It is the method of preparing the crushed coal which is so novel. The conventional method of coal crushing is replaced by a process relying upon the electro-hydraulic effect. This provides a means of converting electrical energy directly into mechanical energy. The effect is produced in a liquid, say water, through which a succession of high voltage discharges is passed. A spark channel is formed during each discharge and this expands instantaneously. The liquid bounding the channel acquires a very high radial acceleration and its momentum produces expansion and cavitation. The volume of a cavity formed in this way is considerable. A spark of 100 mm in length can produce a cavity of 1½ litres. The cavities collapse with a speed exceeding that of sound and this effect is followed by a hydraulic shock effect. The combined effects of the discharge are therefore an extremely high hydraulic shock pressure (in the region of 100,000 atm.), instantaneous cavitation and a very high emission of ultra-sonic energy. These joint mechanisms, it is claimed, can produce particle sizes in the very fine ranges without preliminary preparation of the feed material. As a result of a trial run on Moscow brown coal, particles were produced fine enough to pass through ordinary filter paper of pore diameter 3.5 to 10 microns. This coal was so reactive that it ignited spontaneously after drying at 80°C.



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This process has been applied to the crushing of ash discharge from gas producers and power stations. Apart from the particle reduction an interesting side effect was that nearly all the valuable elements contained in the ash were transferred into solution.

"Electro-Hydraulic Crushing of Coal" by B. I. Losev, A. N. Mel'nikova, F. Ya. Saprykin and L. A. Yutkin, *Vestnik Akademii Nauk SSSR*, 1959 (6), 62-65.

Basalt for Chemical Plant

THE use of basalt as non-metallic material of construction is surprising. This material in the cast form has a number of excellent properties which commend it to the plant user; it will resist thermal shocks up to 200°C, and it will withstand temperatures in the range 400-600°C. Perhaps its most useful property is resistance to abrasion and in this respect it is more than twenty times more resistant than cast iron as measured by grinding wheel tests. In Czechoslovakia where it is being widely used, current applications are for pipes of varying lengths and diameters, for tiles of flooring which has to stand up to hard wearing conditions, for ball and rod mill linings, and in the fibrous form as a thermal insulant. It is particularly suitable for such applications as the hydraulic conveying of masses of hard sharp particles. Its other uses include the lining of flotation cells in ore dressing plants, the lining of dust arresting equipment, for example in power stations, for chutes which have to handle hard and gritty materials, for lining the inside of bunkers, and as a tank lining material. Since it is easy to cast—pipes for example are made by a centrifugal casting method—it seems likely that such components as pipebends which are normally susceptible to erosion—a case in point being the discharge connection from jet-ejectors to the intercondensers of multistage pumping vacuum sets—will be among the additional applications for this material. Its use in centrifugal pumps handling abrasives appears to be another possibility.

Heat Exchangers for High Temperatures

WHAT type of heat exchanger should be used for very high temperature applications forms the subject of a recent A.I.Ch.E. paper*. As in low temperature processes it is desirable that exchangers used at high temperature systems, for example in reactor cooling circuits, should be as compact as possible. In the work cited a number of types were tested in a high temperature loop. In all cases the heating medium was Na-K and the coolant was either another Na-K stream or air. The maximum temperature of the trials was 1500°F and the exchanger types were straightforward shell and tube models, wire wound extended surface types and plate fin models resembling those now becoming popular in low temperature technology. The purpose of these trials however was not transfer performance. The main thing was to discover how these various types behaved under thermal shock conditions. In the tests the Na-K alloy was raised and lowered rapidly and repetitively through a temperature of 300°F. The features of the designs which were of importance in reducing stress to a minimum were the ability to distribute the liquid metal evenly through the exchanger surface and the fit of the parts in order to give good joints. Flow distribution is important since mal-distribution will either aggravate or cause uneven expansion and therefore set up unnecessary thermal stresses.

Of the various types tested the best proved to be the wire wound extended surface tube.

"1500°F Liquid Metal Heat Exchanger Design Development Program" by Chas. C. Eckles, Harrison Radiator Division, G.M.C.

DIARY

The Institution of Chemical Engineers

January 29. *North Western Branch.* At Midland Hotel, Manchester. Annual General Meeting and Annual Dinner and Dance. **3.30 p.m.** and **7 p.m.**

February 2. At The Geological Society, Burlington House, London, W.1. "Steam-oxygen Gasification of Fine Sizes of Coal in a Fluidised Bed at Elevated Pressure," by A. M. Squires. **5.30 p.m.**

February 3. *Midlands Branch.* At The Midland Hotel, Birmingham. "The Exchange of Deuterium between Hydrogen and Liquid Ammonia," by P. J. Bourke and J. C. Lee. **6.30 p.m.**

February 18. *Scunthorpe Group.* At Grimsby College of Further Education, Nuns' Corner, Grimsby. Symposium "Prediction of Chemical Engineering Design Data," papers by M. K. Mong-Hansen, J. Rudkin and R. Williams. **7.30 p.m.**

February 23. At The Geological Society, Burlington House, London, W.1. "Vibratory Ball-Mills," by H. E. Rose. **5.30 p.m.**

The Society of Instrument Technology

January 26. At 26 Portland Place, London, W.1. Symposium on Flame Failure Detection. **6.30 p.m.**

February 11. At 26 Portland Place, London, W.1. "Measurement, Automatic Control and Data Reduction as applied to a Cyclic Plant," by T. A. Lucas. **6.30 p.m.**

February 23. At 26 Portland Place, London, W.1. "Backscatter method of Wall Thickness Measurement," by D. F. White and L. E. Taylor. "Ultrasonic Resonance Method of Wall Thickness Measurement," by M. V. James. **6.30 p.m.**

The Institution of Mechanical Engineers

January 27. At 1 Birdcage Walk, London, S.W.1. "Technical and Economic Aspects Covering the Ocean Transport of Liquid Methane," by Dr. J. J. McMullen. **5. p.m.**

The Chemical Society

January 28. At Liverpool University. "Progress in the Study of Hetrogeneous Catalysis," by Professor Kemball. **5 p.m.**

February 29. At Oxford University. "Chemical Engineering Aspects of Atomic Energy," by Professor P. V. Danckwerts. **8.15 p.m.**

The Institute of Plant Engineers

February 2. At White Lion Hotel, Church Street, Peterborough. "Industrial Metering." **7.30 p.m.**

February 9. At Engineers' Club, Albert Square, Manchester. "Problems in Chemical Engineering Maintenance," by J. C. Veale. **7.15 p.m.**

Other Events

February 15-17. At Old Hall of Royal Horticultural Society. Commercial and Industrial Refrigeration Exhibition.

February 22-26. At Earls Court. Engineering Materials and Design Exhibition and Conference.

February 25 and 26. National Fire Protection Conference at the Connaught Rooms, London, W.C.2.

TRENDS IN SCIENTIFIC AND TECHNICAL MANPOWER

CHEMICALS is one of the four major industry groups ,which between them, in 1959 employed two-thirds of all scientists and engineers in manufacturing industry, but accounted for only one-third of all employees in manufacturing industry. The same four groups accounted between them for nearly 70% (10,100) of manufacturing industry's net gain in scientists and engineers between 1956-59. In 1956* employers were asked to state how many qualified scientists and engineers they thought they would need by 1959, on the assumption that the required number of recruits would be available. For chemicals and allied trades this forecast amounted to 20.4%. The actual increase was 45.4% so that the figure for scientists and engineers employed as a percentage of total employed rose from 2.7% to 3.7%. For mineral oil refining the 1956 forecast of a 47.5% increase in requirements was close to the 50.3% advance which actually occurred. This raised the figure for scientists and engineers as a percentage of the total employed by the industry to the extraordinarily high level of 7.0% from the already high one of 5.2 in 1956.

Classified by branch of science or engineering, we find a different pattern. In 1956, there were estimated to be 1500 chemical engineers employed and the forecast for 1959 was 2200. Actual number employed was between 1900 and 2000, and the new forecast for 1962 requirements is 2700.

In general the Advisory Council on Scientific Policy has been pleased to note in its report for 1958-59 a rather higher rate of growth in the employment of scientists and engineers than had been expected, and a higher output of trained men as well. Furthermore the demand for scientists and engineers shows no signs of abating. The proportion taking up employment in industry has increased, and the share taken by defence, both in industry and government departments, has fallen to about one third of the total. A greater proportion of scientists and engineers appears, therefore, to be finding its way into civil employment of direct benefit to the national economy. The number of science teachers in schools has been increasing, but the increase in the numbers of well-qualified teachers of mathematics, physics and chemistry, has not, unfortunately, been sufficient to meet all the demands arising from the increase in the number of children studying science. The Council has emphasised that great efforts will be required if the shortage of teachers is not to hinder the development of science courses, particularly in schools other than grammar schools.

* Scientific and Engineering Manpower in Great Britain, 1959. Report of Advisory Council on Scientific Policy, Committee on Scientific Manpower. Cmnd 902. H.M.S.O. 3s.

Annual Report of the Advisory Council on Scientific Policy 1958-59, Cmnd 893. H.M.S.O. 1s

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FROM THE PRESIDENT

INTRODUCTION TO INSTRUMENTATION ISSUE OF ''BRITISH CHEMICAL ENGINEERING''

I welcome the initiative of ''British Chemical Engineering'' in devoting a complete issue to the problems of instrumentation and automation in the field of chemical engineering and am glad of the opportunity to send a message of goodwill.

The British chemical industry has been one of the most enterprising of British industries and has reaped the benefit by an unusually rapid rate of expansion. An important part of this enterprise has been in applying instruments and automatic controls. At one stage instrumentation on plants was largely limited to what was needed for measuring the basic physical properties of temperature and pressure. Since then developments have occurred in several directions. A wide range of physical properties is measured, very often as checks on chemical composition. In addition, the signals from instruments may be applied to control devices and we are heading towards the time when computers will ever more widely be used to analyse these signals and operate the controls with greater refinement in order to optimise production.

During the past two years output of our industry has increased in value by about 14% and the trend is continuing. Our exports have correspondingly increased. The technical demands from chemical engineers have been a constant spur to our industry stimulating its further development and I wish them well in all their future efforts.

L. A. Woodhead

L. A. WOODHEAD
President.
Scientific Instrument Manufacturers' Association.

66.02-52

AN OPTIMISING CONTROL FOR THE CHEMICAL PROCESS INDUSTRIES

Operation of a special-purpose computer for obtaining maximum output from a catalytic process for manufacture of styrene

by D. H. ARCHER, B.S., Ph.D.

CHEMICAL engineers by tradition have designed automatic control systems to keep constant those variables in a chemical process which are considered to be of primary importance. There is now, however, a growing interest in devising controls which will continually and automatically adjust the independently variable process quantities so that the overall performance of process is optimised.[1] The variables or measured quantities associated with a chemical process may be thought of as the pressure, temperature, composition and flowrates of all input, output and internal material streams, and the flowrates of energy in the forms of heat and work between the process and the surroundings or between various parts of the process. There is also a large group of other internal process parameters which are not directly connected to material and energy streams, but which are process variables; these may be, for example, catalyst activity in a reactor, the liquid level in a vapour condenser or spark advance in an internal combustion engine.[2] All the process variables, however, can be divided into two groups—independent and dependent variables.

Independent variables are those process quantities which fall in one of the two following groups:

(1) controlled variables—those process quantities which can at any time be varied within certain limits by an operator or by a control system; and

(2) uncontrolled variables—those process quantities which are determined by arbitrary factors external to the process and which may fluctuate with time. The feed quantity and composition to a distillation process, for example, may be uncontrolled variables if they are determined by previous steps in a chemical manufacturing operation.

Dependent variables are those measurable process quantities whose values are completely determined by the values of the independent variables. Fig. 1 is a conceptual process diagram which summarises these concepts and is helpful in discussing the problem of optimising a chemical process.

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Before a process can be optimised by any system of control, it is necessary to specify a single variable in the process which reaches a maximum (or, in some cases, a minimum) when the process is operating at its optimum. This optimised quantity must be either a dependent process variable which can be directly measured or a function of both dependent and independent process variables. (Unless at least one dependent variable is involved in this function, the optimum operating conditions will be independent of the manner in which the process is operating.) Many chemical processes are said to be optimised when the rate at which they produce profit reaches a maximum; operating profit can then be used as the optimised quantity, provided that it can be calculated from measurable process variables. Under other circumstances the optimised quantity may be the production rate from the process, which is to be maximised, or process operating costs, which are to be minimised.

When a chemical process is to be optimised, there are—almost without exception—certain limiting conditions. The independent, controlled process variables as a rule can be varied only within certain physical bounds. The flow of raw materials to a reactor, for example, may be limited by the capacity of a pump; or the pressure in a distillation column, by the materials and mode of its construction. Limiting conditions may also be imposed on some of the dependent variables of a process which is to be optimised. For example, it may be desired to minimise operating costs of a chemical reactor subject to the conditions that the production rate of the product exceeds a fixed minimum and the quantity of by-products produced is less than a fixed maximum.

There are two different approaches to the problem of automatically optimising a chemical process, such as that pictured in the diagram, by appropriate adjustments of the controlled variables. The first approach is to construct a model of the process. This model may be:

(1) A scale model of the process.[4] The process equipment or portions of it are reconstructed in miniature; the dimensions are scaled and reduced quantities of materials and energy are fed to the process. The problem connected with this procedure is proper method of scaling dimensions, flowrates, times, material properties, etc.[1]

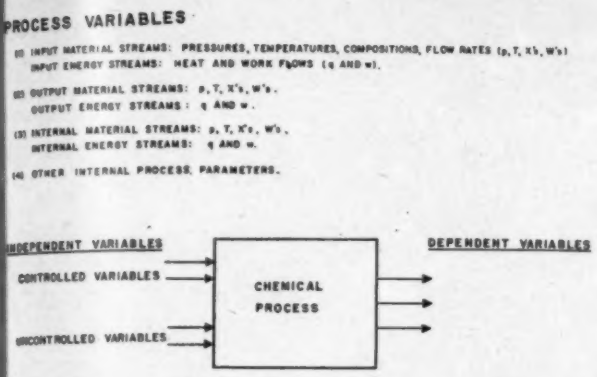

PROCESS VARIABLES
(1) INPUT MATERIAL STREAMS: PRESSURES, TEMPERATURES, COMPOSITIONS, FLOW RATES (p, T, x's, W's)
INPUT ENERGY STREAMS: HEAT AND WORK FLOWS (q AND w).
(2) OUTPUT MATERIAL STREAMS: p, T, X's, W's.
OUTPUT ENERGY STREAMS: q AND w.
(3) INTERNAL MATERIAL STREAMS: p, T, X's, W's.
INTERNAL ENERGY STREAMS: q AND w.
(4) OTHER INTERNAL PROCESS PARAMETERS.
INDEPENDENT VARIABLES
CONTROLLED VARIABLES
UNCONTROLLED VARIABLES
CHEMICAL PROCESS
DEPENDENT VARIABLES

Fig. 1. A conceptual process diagram useful for discussing problems of optimising chemical processes.

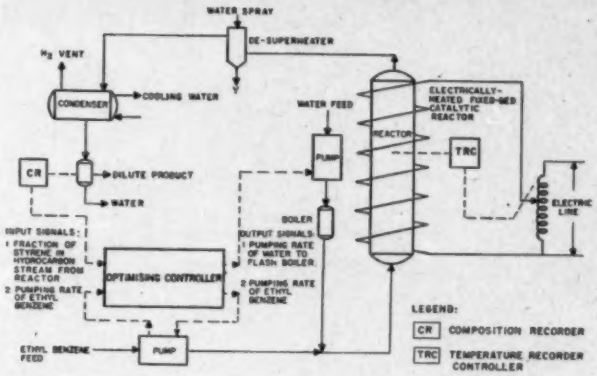


Fig. 2. The OPCON optimising control of the catalytic dehydrogenation of ethyl benzene.

(2) An analogue model of the process. Electrical networks have been used as analogue models of heat-transfer equipment and have been used to solve problems of optimum design of such apparatus.[4] The problem connected with this procedure is to discover a close analogue to a chemical-engineering process which can be used as the basis for the construction of a model.

(3) A system of mathematical equations describing the relations between the independent and the dependent variables of the chemical process.[6, 9, 10, 14] These equations—with suitable values of constants and appropriate boundary values for the process—together with a digital or analogue computer capable of their solution are a mathematical model of the process. The problem involved here is determining the equations, constants and boundary values for the equations and devising ways of solving the equations for the optimised quantity in terms of the controlled independent variables of the process.

Once the models have been constructed, experimentation (or mathematical manipulation) can be carried out on the models to determine the values of the controlled variables which maximise (or minimise) the optimised quantity for any values of the uncontrolled variables which may occur. Considerable experimentation may be required to cover the range of variation of the uncontrolled independent variables. The problem may also be complicated if the process is to be optimised under conditions such that the uncontrolled variables are fluctuating in value.

The second approach to optimisation of a chemical process is to experiment directly on the process itself.[3, 13] Small step changes can be made simultaneously in one or more of the controlled variables; this is called a "move". The process is then allowed to approach the new equilibrium conditions, and the optimised quantity is computed from measured values of the process variables. Its value is compared with values determined after previous moves; the results of this move and of previous moves are then used to make a logical decision about the next move required to bring the process to its optimum operating point. This empirical search procedure to discover the values of the controlled variables which will optimise the chemical process is most likely to be successful if:

(1) the optimised quantity has a single, well-defined maximum value within the allowable range of variation of the controlled variables;

(2) the fluctuation rate of the optimised quantity due to drifts in the uncontrolled variables is small in comparison with the rate due to the moves of the controlled variables; and

(3) "random" fluctuations or noise in the optimised quantity are small in comparison to changes in the optimised quantity brought about by the moves.

A special-purpose logical computer has been developed by the WESTINGHOUSE ELECTRIC CORPORATION to optimise chemical processes.[5] This device, called OPCON optimising control, employs the second approach to optimisation and performs the following functions:

(1) It makes step changes in one, two or more of the controlled variables either by shifting the set point on a conventional closed-loop controller or by directly actuating a control device such as a valve on a pipeline or the speed control on a positive displacement pump. (The controlled variables which are not regulated by the optimising control can be maintained constant by standard controllers.)

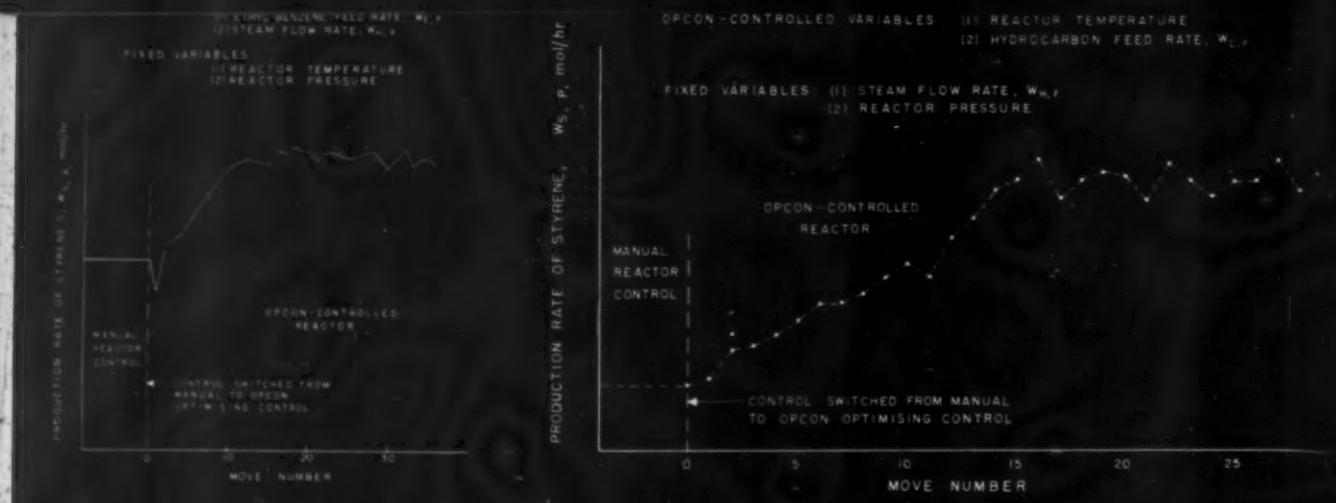
(2) After a preselected time period has passed, it accepts signals from measuring devices which indicate values of all those variables concerned in determining the optimised quantity.

(3) It computes the optimised quantity and compares this value with best value determined by previous moves. It is this comparison which determines the result of the move.

(4) It decides on the basis of this result and on the basis of the moves which have been made previously what move should be made next. Specifically, the device establishes which of the variables under its control will be changed in a given move, whether the variable will be increased or decreased, and what the magnitude of the variation should be.

The rules by which the control makes a decision about its next move on the basis of its past moves and their results are called the *strategy* of the machine.

It has been shown[6] that if a control device adjusts only a single process variable, there is a "best" strategy for determining the process optimum, provided that there is not more than one optimum or relative optimum in the operating range of the process. This "best" strategy assures that the number of moves required to approach within a given neighbourhood of an optimum is always finite and tends to minimise the number of moves to optimise processes under a wide variety of operating conditions. If, however, more than one variable is adjusted to optimise the process, no "best" strategy can be found[7] unless the



form of the relation between the optimised quantity and the controlled variables is known.[12]

Two illustrative applications of the optimising control will indicate how this device can be used to optimise a chemical process. The first application describes an existing installation of the device at the DOW CHEMICAL CO. and some of the results which have been achieved. The second application describes a study made prior to installation of a second optimising device. It reviews some of the analyses carried out to determine the applicability of optimising control to a full-scale distillation column used to separate a mixture of iso- and normal-butane at the Marcus Hook Refinery of the SUN OIL CO.

Application 1: Catalytic Dehydrogenation of an Ethylbenzene

$$C_6H_5CH_2 - CH_3 \rightarrow C_6H_5CH = CH_2 + H_2$$

The Process

Two streams, water and the ethylbenzene, E, to be dehydrogenated are fed by means of variable-speed, positive-displacement pumps to an electrically heated, fixed-bed catalytic reactor (see Fig. 2). The water is vaporised in a flash boiler before being mixed with the hydrocarbon; water vapour serves as a heating and vaporising medium for the feed, as a diluent in the reactor and as a deterrent to the formation of carbon on the catalysts. The gaseous mixture emerging from the reactor is cooled and condensed. The liquid passes to the separator where the styrene, S, mixed with unreacted ethylbenzene and small quantities of by-products, is decanted from a water phase.

Optimised Quantity

In the initial tests of the control the optimised quantity for this dehydrogenation process was the flowrate of the styrene product, S, in mol/hr. Since this dehydrogenation reaction can be written,

$$E \rightarrow S + H_2$$

the flowrate in mol/hr of total hydrocarbons, W_P, leaving the reactor is equal to the mol/hr of E feed, $W_{E,F}$ (if it is assumed that side reactions are negligible). Therefore:

$$W_{S,P} = x_{S,P}\, W_P = x_{S,P}\, W_E$$

where $x_{S,P}$ is the mol fraction of styrene in the hydrocarbon mixture from the reactor.

Signals proportional to $x_{S,P}$ and W_E are fed to the optimising control from the composition recorder and from the variable-speed drive on the hydrocarbon feed pump. The control computes the flowrate of the styrene, $x_{S,P}\, W_P$, and operates the process in such a way as to maximise this quantity. Figs. 3 and 4 show how in several of its initial runs the optimising control quickly adjusted the controlled variables of the dehydrogenation process to reach and maintain a maximum production rate from the reactor.

While the optimising control had as its first goal maximising styrene production from the reactor, it can easily be adjusted to maximise operating profit, £/hr, from the reactor. If it is assumed that no by-products are produced in the process, a simplified equation for calculating this profit from measured process quantities is

$$\text{£/hr} = V_S\, x_{S,P}\, W_P - V_E\, x_{S,P}\, W_{E,F} - V_H\, W_{H,F} - V_D\, W_P$$

where V_S and V_E = the costs or prices of the ethylbenzene and the purified styrene respectively, £/mol;

V_H = the cost of producing water vapour fed to the reactor, £/mol;

V_D = the cost per mol of distilling the hydrocarbon mixture from the reactor to produce purified styrene, £/mol; and

$W_{H,F}$ = the flowrate of water to the process, mol/hr.

This profit equation can be rearranged and simplified to give

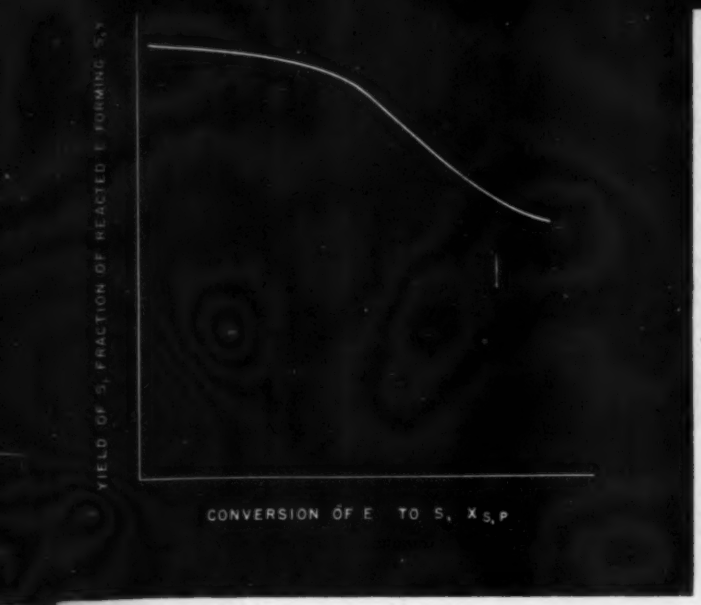
$$\text{£/hr} = (V_S - V_E)\, W_{E,F}\, [x_{S,P} - (V_D + V_H n)/(V_S - V_E)]$$

where n is ratio of mols of water feed to mols of E feed. As a first rough approximation, the term

$$(V_D + V_H n)/(V_S - V_E)$$

can be considered a constant, k, to be subtracted from the mol fraction of styrene in the hydrocarbon stream from the reactor, $x_{S,P}$, before multiplication by the term $(V_S - V_E)\, W_{E,F}$ to calculate the profit rate; the value of k must be less than 1.0 if £/hr is to be positive. The control can be provided with a dial by which a signal proportional to k can be introduced to the device. It can then determine the profit rate and operate the reactor in such a way as to maximise £/hr.

At high temperatures and large values of $x_{S,P}$, it is no longer true that the quantity of by-products produced in the reactor is negligible. It has been found that the yield of



the process, y—the fraction of the total ethylbenzene reacted which forms styrene—decreases as $x_{S,P}$ increases and can be approximated by a function of $x_{S,P}$ alone (see Fig. 5). In case y is appreciably less than 1.0, the profit equation can be modified to give

$$\text{£/hr} = V_S\, x_{S,P}\, W_P - V_E\, x_{S,P}\, W_P/y + V_c\,(1-y)\, x_{S,P}\, W_P/y - V_H\, W_{H,F} - V_D\, W_P$$

where V_c is the price received for by-products recovered in the distillation process to purify styrene, per mol of ethylbenzene to by-products, £/mol.

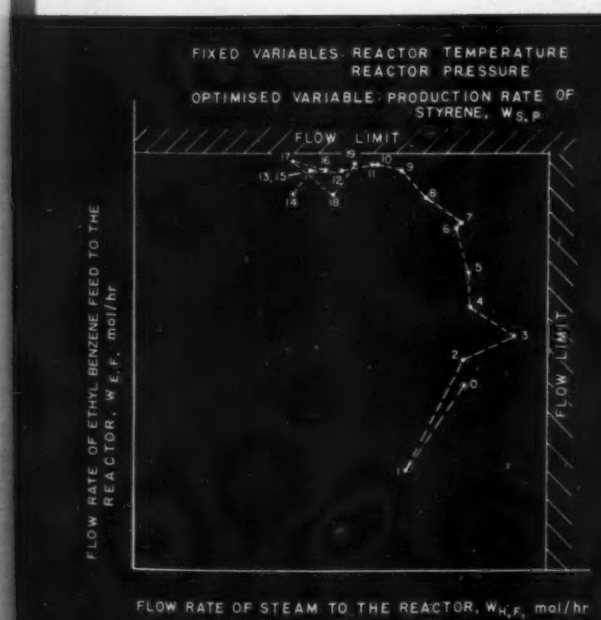
If, then, signals proportional to W_P, $x_{S,P}$, $W_{H,F}$ can be provided to the profit computer together with the economic data—V_E, V_S, V_c, V_H, and V_D—and the functional relation shown in Fig. 2, the rate of profit produced by the process can be determined at any instant, and the control can proceed to maximise this quantity.

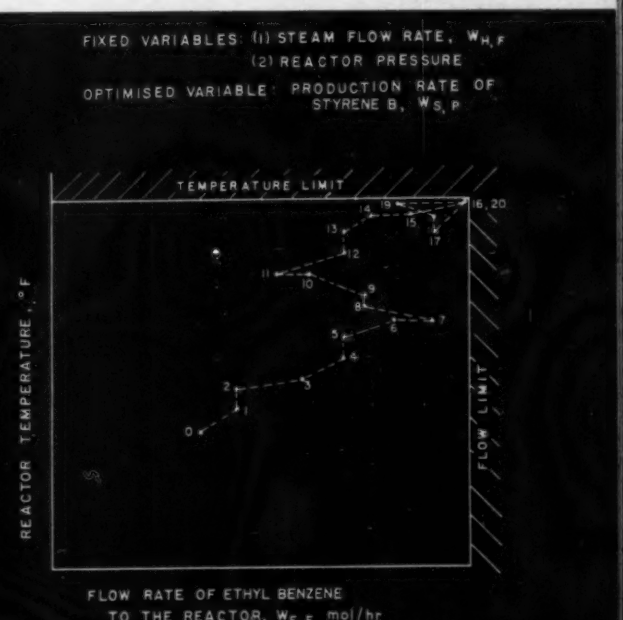
Controlled Variables

There are four independent controlled variables of primary importance associated with this catalytic dehydrogenation process; theses are: (1) pressure in the reactor; (2) the reaction temperature (determined by the electrical energy input to the heating coils of the reactor); and (3) and (4) the flow rates of ethylbenzene feed, $W_{E,F}$, and of steam, $W_{H,F}$, to the reactor. The optimising control for this installation has the capability of adjusting two of these quantities. And two process variables—$W_{E,F}$ and $x_{S,P}$—appear in the equations for both the production rate of styrene, $W_{S,P}$, and the operating profit rate, £/hr. The flow, $W_{E,F}$, can be directly controlled and is regulated by the optimising control; but $x_{S,P}$ depends on all four of the process variables mentioned above and cannot be varied directly.

Temperature is the single variable which has the strongest effect on $x_{S,P}$; increasing temperature increases $x_{S,P}$ up to a point. Excessively high temperatures, however, lead to the formation of undesired by-products and to the rapid deterioration of the catalyst. For the initial tests, therefore, temperature in the reactor was maintained constant at a safe value by an auxiliary controller. A decrease in pressure has also been found to increase $x_{S,P}$. For technical reasons, however, it has been found inadvisable to reduce the total pressure below 1.0 atm; and so it has been fixed at this value. Increasing steam flow has in part the same effect as decreasing the total pressure in the reactor, since greater quantities of steam reduce the partial pressure at the reactant, E, and products, S and H_2 The presence of steam also tends to keep the catalyst activity at high value. The control in its initial tests regulated steam flow and the flow of feed to maximise the production rate of the reactor. In further tests it adjusted temperature and ethylbenzene feed flows to optimise production.

Fig. 6 shows how the control adjusted steam and hydrocarbon feed-flow rates to the reactor to produce the results shown in Fig. 3. The reactor was first brought to equilibrium under manual control at the conditions marked "0"; the optimising control was then connected to the process. The control was set manually to make its first move from the initial operating conditions at 0 to 1. This move resulted in a decrease in the production rate of styrene from the reactor as shown in Fig. 3. The control, following this decrease, made a logical decision about the next choice of an operating point and increased the flowrates of both hydrocarbon feed and steam to point 2. The production rate of styrene sharply increased. The control, because production continued to increase, continued to adjust upward both flowrates until at point 3 the steam flow reached a maximum. The control then decreased steam until it reached its lower limit, but continued to increase


FIXED VARIABLES: REACTOR TEMPERATURE
REACTOR PRESSURE
OPTIMISED VARIABLE: PRODUCTION RATE OF STYRENE, $W_{S,P}$
FLOW LIMIT
FLOW LIMIT
FLOW RATE OF ETHYL BENZENE FEED TO THE REACTOR, $W_{E,F}$, mol/hr
FLOW RATE OF STEAM TO THE REACTOR, $W_{H,F}$, mol/hr


FIXED VARIABLES: (1) STEAM FLOW RATE, $W_{H,F}$
(2) REACTOR PRESSURE
OPTIMISED VARIABLE: PRODUCTION RATE OF STYRENE B, $W_{S,P}$
TEMPERATURE LIMIT
FLOW LIMIT
REACTOR TEMPERATURE, °F
FLOW RATE OF ETHYL BENZENE TO THE REACTOR, $W_{E,F}$ mol/hr

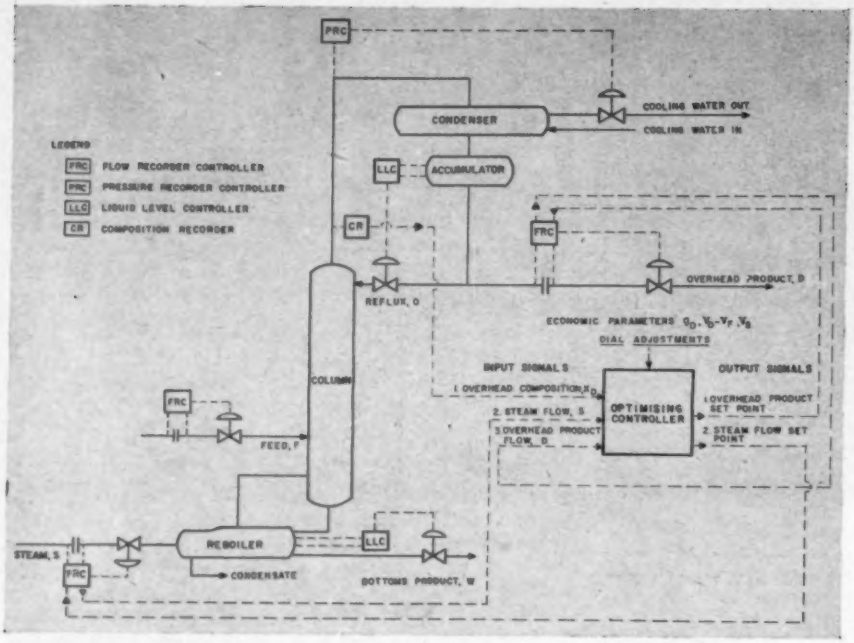


Fig. 8. OPCON optimising control of a distillation process for separating a binary light hydrocarbon mixture.

ethylbenzene feed rate until this flow reached its upper limit. Production of styrene plotted in Fig. 3 was almost continuously increased until the region of the optimum operating conditions was reached. Here the control continues to search for the precise optimum location.

Figs. 4 and 7 show the results of a test run in which reactor temperature and hydrocarbon flowrates were regulated by the control to give the maximum production rate of styrene. Both the temperature and feed rate were ultimately increased to their maximum allowable limits. The increase in temperature was continual. The increase of ethylbenzene feed was interrupted during moves 7-11 because the large increases of production rate resulting from temperature increases obscured the relatively small decreases resulting from decreases in feed rate. At move 10-11 temperature was held constant and the effect of decreasing feed became evident. From this move forward both temperature and feed were increased to their upper limits.

While, in maximising production, the controlled variables were in each case adjusted to limiting values, it is expected that when profit is the optimised quantity, the process will be optimised at moderate temperature and ethylbenzene feed quantities.

Uncontrolled Variables

The uncontrolled variable most important in determining the production rate of S or the operating profit rate of the dehydrogenation process is the catalyst activity. The catalyst slowly deteriorates with time and thus the mol fraction of S in the total hydrocarbon from the reactor, $x_{S,P}$, tends to decrease if operating conditions are not adjusted. Other random fluctuations of temperature distribution in the reactor, purity of the reactant, and the temperature of the feed stream also affect the value of $x_{S,P}$. It has been observed that the point of optimum operation also shifts with catalyst activity and the random fluctuations of the other uncontrolled process variables. The OPCON regulates these two controlled variables—for example, $W_{E,F}$ and $W_{H,F}$ or $W_{E,F}$ and reactor temperature—to optimise the process.

Time of Fluctuations

How rapidly the optimum operating point of the reactor drifts due to changes in catalyst activity depends strongly, of course, on the particular catalyst used. The activity and selectivity of some catalysts change appreciably within periods of 2-3 hr; other catalysts can be used without regeneration for 4-5 wk or longer. The catalyst used in these initial runs requires regeneration only after long runs; the shift in the optimum operating point is, therefore, relatively slow. On the other hand, the miniplant dehydrogenation reactor from which the information presented here was obtained reaches equilibrium rapidly after changes in flowrates, but due to hold up in separator-accumulator and in instrument lines, a period of about 45 min. is required before an equilibrium measure of $x_{S,P}$ can be obtained after a change in operating variables. The time between successive changes of operating conditions shown on Fig. 3 is 45 min. When the temperature in the reactor is varied, the approach to equilibrium is slower; the time required for the catalyst bed temperature to equalise after an increase in the heat input to the reactor is about 1.5 hr. These equilibrium times might be reduced by special equipment design. They are short enough, however, for the optimising control to maximise the production from a dehydrogenation reactor using a catalyst which requires regeneration only after 30 hr or longer.

Application 2: Distillation of a Binary Mixture of iso- and n-butane

The Process

Fig. 8 is a schematic diagram which shows a second application of the OPCON control to an industrial optimising problem. The process to be controlled is the separation of a binary mixture of butanes in a 6-ft-diameter distillation column of 30 plates. Input streams to the process are the hydrocarbon feed to the column, F, steam to the reboiler, S, and cooling water to the condenser; output streams are an overhead and a bottoms hydrocarbon product, D and W, steam condensate from the reboiler, and a hot water stream from the condenser.

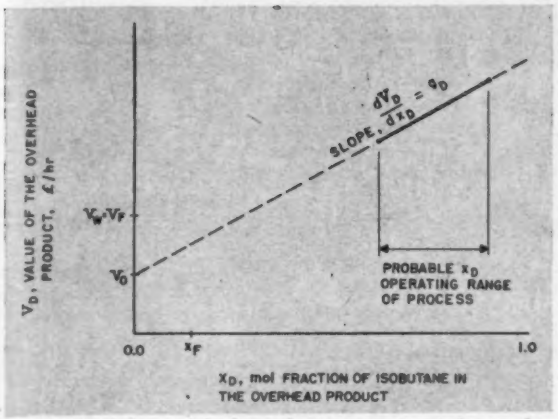


Fig. 9. Values of hydrocarbon streams entering and leaving distillation process.

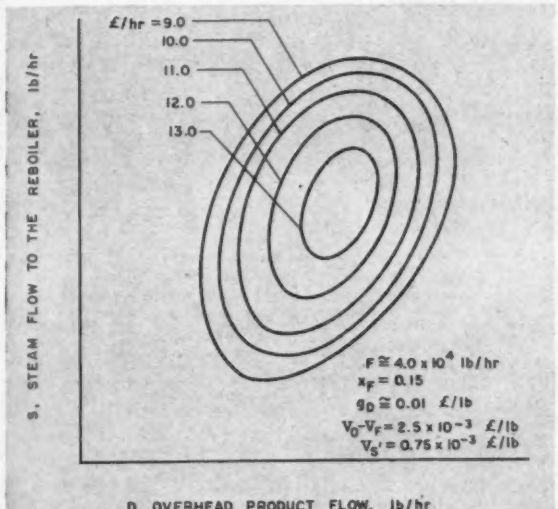


Fig. 10. Operating profit rate of distillation process as determined by operating conditions.

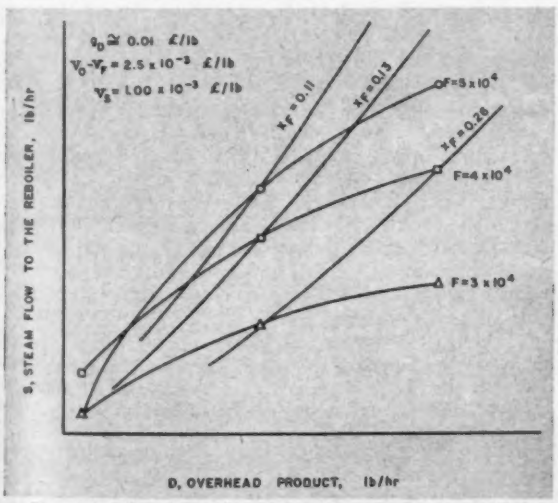

$g_D \cong 0.01$ £/lb
$V_o - V_F = 2.5 \times 10^{-3}$ £/lb
$V_S = 1.00 \times 10^{-3}$ £/lb
$x_F = 0.11$
$x_F = 0.13$
$x_F = 0.28$
F=5 x 10⁴
F=4 x 10⁴
F=3 x 10⁴
S, STEAM FLOW TO THE REBOILER, lb/hr
D, OVERHEAD PRODUCT, lb/hr

Fig. 11. Location of economic optimum operating conditions as determined by feed quantity and composition. Note: Economic parameters have been shifted from true values in Figs. 10 and 11.

Optimised Quantity

It has been decided to maximise the operating profit rate of this process by means of OPCON optimising control. An equation relating the profit rate, £/hr, to directly measured process variables is

$$\text{£/hr} = V_D\ D + V_W\ W - V_F\ F - V_S\ S$$

where D, W, F and S are the flowrates of overhead product of distillate, bottoms product, feed and steam, respectively, lb/hr. The letter Vs stand for the values or price, of the various streams in £/lb. V_S should include the cost of the cooling water used in the condenser for each lb. of steam fed to the reboiler as well as the cost of the steam.

The profit equation can be simplified by combining with it the material balance equation $F = W + D$ and the economic fact that $V_F \cong V_W$.

$$\text{£/hr} = (V_D - V_F)\ D - V_S\ S$$

The value of the overhead product has been determined to be a linear function of the mol fraction, x_D, of isobutane in the distillate (see Fig. 9) over the probable operating range of the process. And

$$\text{£/hr} = [g_D\ x_D + (V_o - V_F)]\ D - V_S\ S$$

where g_D = the slope of the product value curve shown in Fig. 9; and

V_o = the intercept of this curve on the ordinate of Fig. 9.

Three pieces of economic data, g_D, $(V_o - V_F)$ and V_S, are fed to the optimising control by adjusting dials; thereafter, the controller computes profit from measured values of x_D, D and S; it operates the process in such a way as to maximise this quantity.

Controlled Variables

In this binary distillation process there are three possible variables which can be independently controlled. Coincidently there are also three process variables involved in the profit equation. Two of these, D and S, can be easily and directly controlled; the optimising controller will be given the task of adjusting D and S so that £/hr will be a maximum. The third variable in the profit equation, x_D, cannot be directly controlled. Water flow to the condenser is, for this reason, chosen as the third independent variable for control. The water flow is regulated to maintain the pressure in the column at some constant selected design value.

Some rough preliminary calculations have been carried out to determine whether the profit rate actually does pass through a maximum as D and S are varied within the operating limits imposed by the tower design. A feed quantity and composition, F and x_F, and an overall plate efficiency were assumed; plate-to-plate calculations were carried out to estimate x_D at various values of D and S. The profit rates, £/hr, were calculated for the various operating conditions by the equation given above. A plot which shows the results of such calculations is given in Fig. 10. From this diagram, the profit rate for a given feed can be determined for any values of D and S by interpolation between the "iso-buck" lines of constant £/hr. It is clear from this diagram that in this instance there is a particular operating condition which leads to maximum profit. The function of the optimising control is to determine the location of this point for the actual column and operate the process there.

Uncontrolled Variables

The butane feed to this process comes from a previous step in a long sequence of processing steps. The quantity, the composition and the thermal condition fluctuate with time, and it does not seem feasible to control these fluctuations. In addition to feed fluctuations, there are variations in steam temperature and pressure and in other environ-

mental conditions which will affect the operation of the column and its operating profit. Additional preliminary rough calculations were carried out to estimate the effect of feed flowrate and composition on the location of the optimum operating conditions—that is, on the values of D and S which yield the maximum profit rate. Fig. 11 shows the results of such calculations. The feed quantity and composition are located at the intersection of the parametric F and x_F lines; the D and S lines which yield the maximum £/hr are then located on the abscissa and ordinate of the plot. It is evident that there is a significant change in the optimum operating conditions with changes in the feed. There will also be shifts in the optimum operating conditions when the economic factors—V_D, V_F and V_S—change from time to time. The control automatically adjusts D and S so that the column operates at the point of maximum profit.

Time of Fluctuations

Fluctuations in feed rate and composition are expected to occur within a period of 8 hr or greater; these variations are expected to be the most important factors in determining the shift of the optimum operating point for the column. Preliminary calculations and actual experiment indicate that the column essentially reaches new equilibrium conditions within 1 to 1.5 hr after a change in D or S. The controller is able, therefore, to follow quite closely the shifts of the optimum operating point.

These applications point out the five points which must be considered in deciding whether the performance of a chemical process can be improved by OPCON optimising control:

(1) Can the process be represented by a diagram such as in Fig. 1?

(2) Is there a single, well-defined quantity concerned with the process which is to be optimised? Can this quantity be directly measured at any time, or can it be calculated from directly measurable process variables?

(3) Are there one or more of the process variables affecting the quantity to be optimised which can be independently controlled? As these quantities are varied within permissible limits, does the optimised quantity pass through a maximum (or a minimum)?

(4) Do fluctuations or drift in uncontrolled process variables or streams require some shift in the controlled streams in order to maintain the optimised quantity at a maximum (or a minimum)?

(5) Is the time required for the process to reach equilibrium after a change in one or more of the controlled process variables short in comparison with the time period of fluctuations or drift in uncontrolled process variables?

If the answer to each of these questions is "yes", then the process performance may well be optimised by the type of optimising control discussed in this paper.

ACKNOWLEDGMENTS

The results reported in this paper were obtained in the course of two co-operative development projects. The first project, co-sponsored by THE DOW CHEMICAL CO. and WESTINGHOUSE, was directed by JOHN W. BERNARD of DOW and R. I. VAN NICE of WESTINGHOUSE. The second project, co-sponsored by the SUN OIL CO. and WESTINGHOUSE, was directed by ERIC A. WEISS and MARLIN NELSON of the SUN OIL CO. and R. I. VAN NICE of WESTINGHOUSE. The splendid co-operation of these gentlemen and their associates is gratefully acknowledged.

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World's Biggest MEK Plant

Filter section has largest filters ever used in Petroleum Industry

CONSTRUCTION of one of the world's largest MEK dewaxing-deoiling plants for the manufacture of paraffin waxes has recently been completed by Badger Manufacturing Co., Cambridge, Massachusetts, at the Philadelphia refinery of The Atlantic Refining Co. The plant has a rated capacity in excess of 216 million lb. a year of paraffin waxes of low oil content (some as low as 0.2%). Atlantic will market much of the product to manufacturers of wax-coated food packages. The four-acre plant and its adjoining off-site storage, slabbing and packaging facilities cost approximately $18 million.

Basically, Texaco Development Corp.'s MEK (methyl ethyl ketone) solvent dewaxing process is employed. However, the detailed design and final engineering phases were unusually complex as the plant had to be capable of handling eight different feedstocks (light, medium and heavy waxy distillates from a vacuum pipe still) through 14 operations to produce a full line of refined and semi-refined paraffin waxes.

The heart of the process is the filter section where the wax and oil separation takes place. The specially designed filters, with drums 11 in. in diam. and 20 in. long, are said to be the largest in use in the petroleum industry. The chilled wax slurry flows into each filter by gravity. As the drum rotates, dewaxed oil and solvent are pulled through the filter cloth by vacuum. The wax cake built up on the filter surface is washed by solvent sprays and blown free of the filter cloth. The cake is then diluted and put through repulping and refractionating operations for further removal of oil and any other undesirable components still remaining.

Prior to each stage of filtration the wax mix is chilled in a unique system of exchangers and chillers devised by Badger. The section consists of a battery of double-pipe scraped surface exchangers and double-pipe scraped surface chillers arranged in two parallel banks with the drive ends facing each other. The refrigeration system consists of centrifugal compressors, propane condensers, propane receivers, economisers and knock-out drums. The plant has three separate solvent-recovery systems providing products which are stated to be of an extremely high purity.

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AUTOMATIC CONTROL OF FRACTIONATING COLUMNS

A brief review of the elements of automatic control theory is presented and applied to the control of fractionating columns.

by N. J. HASSETT, B.Sc., Ph.D., M.I.Chem.E.

THE control of a continuous distillation process is usually aimed primarily to give one product within a given specification, and second, but almost as important, to lose as little of the desired product at the other end of the column. For a given reflux, alteration of the top product take-off rate changes one for the better at the expense of the other. The degree of separation is enhanced by increase of reflux ratio, which means more steam and cooling water per unit of product, thereby increasing costs and reducing throughput capacity. All these, and other considerations, combine in deciding the limits within which a distillation column shall operate. They also indicate the manner in which a column may be corrected if it goes off balance.

Having decided the optimum process conditions for standard conditions, the problem arises of how best to maintain those conditions against voluntary or involuntary changes such as throughput rates or input composition, or changes in the services such as cooling water inlet temperature or steam supply pressure. The ideal would be for such changes to be sensed before entry to the system and transmitted to a computer controller which would apply the necessary compensating actions to prevent any change in composition of the desired product while maintaining losses at the theoretical minimum. For a complex system like a distillation column, the realisation of this ideal is still far ahead. The best that can be done is to sense any change before it has progressed far and to apply correctives as indicated by the change. This means that a process has to be run somewhat above specification, leaving a margin for such change and correction, or, alternatively, run at near specification limit, bulking the product with purer material if necessary to bring within specification for sale, or use, if the column chances to run below specification for long enough to affect the bulk quality.

In any case, the problem rests with finding the most suitable characteristic or characteristics and points of measurement to give indication of change and deciding what controls to apply in order to counter the change. Before considering these points, it will be useful to review the elements of control theory.

Dr. Hassett *is Senior Lecturer in Chemical Engineering at Loughborough College of Advanced Technology.*

General Principles of Control

A process can usually be subdivided into a number of subsidiary process stages, each of which may be simple or complex, but which in itself can be considered as the smallest unit susceptible to control as a unit. The simplest unit can be characterised by a single capacitance plus a flow rate, and is best expressed in terms of some physical characteristic defining the change, such as temperature, and quantity of control agent. The difference between the value of that physical characteristic and its desired value is called the deviation θ_2, and the amount of control agent necessary to produce steady-state unit deviation is termed the rate factor, $\dot{q}$. The amount of control agent equivalent to unit deviation of the material held in the system is termed the capacitance C. The rate factor and capacitance together determine how the process stage responds to a disturbance. The disturbance itself is defined by the deviation it would cause ultimately if held constant at that value, and is denoted by θ_D.

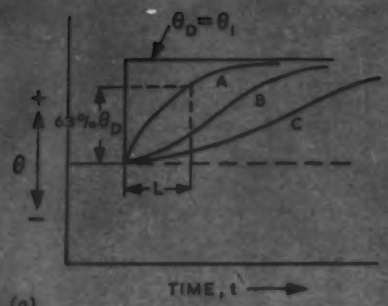
If a sudden and sustained disturbance of magnitude θ_D entered a process stage, running at desired conditions ($\theta_2 = 0$) the deviation would not change suddenly but would build up and eventually reach θ_D. In the simple case just described, the build up would follow an exponential curve to the formula

$$\theta_2 = \theta_D\,(1 - \theta^{t/L})$$

where $L = C/\dot{q}$ and would reach 63% of the final value in time L. This response is shown as curve A in Fig. 1 (a). More complex stages have response curves as shown in curves B and C.

A plate distillation column, or worse, a packed column acts as a large number of process stages in series and the effect of a disturbance takes an appreciable time for a sensible fraction of the potential effect to be noted in the product. Automatic control is designed to put into the system a counterbalancing disturbance to θ_D well before the deviation has reached the tolerance limit of the process. This means that the deviation has to be sensed well before the tolerance limit has been reached, and counteracting action taken. This action is usually designed to be overlarge so as to act quickly, and causes a swing in the other direction so that the recovery curve is cyclic (Fig. 1 (b)).

The controllers commonly used are proportional controllers with or without integral and rate factors, and are



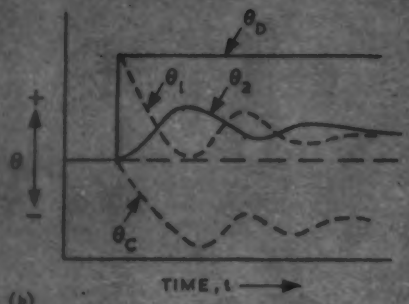


Fig. 1a. Response of process stages to a sudden and sustained input change. Fig. 1b. Response of simple process stage to a step disturbance countered by proportional controller.

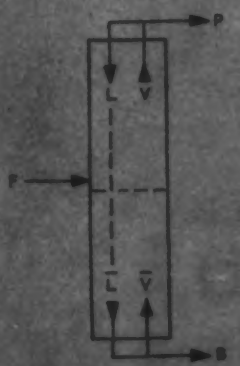


Fig. 2. Block sketch of fractionating column.

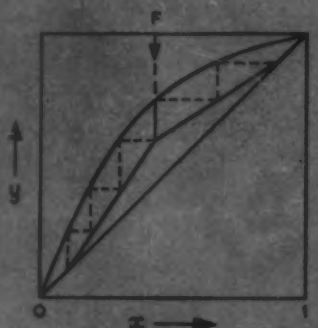


Fig. 3. Simple McCabe-Thiele diagram.

known as single-, two- or three-term controllers accordingly. Briefly, a single-term or proportional controller applies an instantaneous correction which is proportional to the deviation. It cannot reduce the deviation to zero. Integral control reduces the deviation to zero over a time period which is adjustable. Rate control is active against sudden or rapid changes in deviation.

The practice of automatic control is far easier than the theory and can almost be likened to the use of relaxation methods as compared with rigorous mathematical solution of complex problems. Provided that the basic principles are understood, the operation of a complex control system can readily be followed.

Factors Affecting Column Performance

In considering the control of a distillation process, it is useful first to present the general picture and consider which factors determine the performance of a column, and what are the physical characteristics that can be readily measured and which indicate the trend as well as the existing conditions.

The important points can readily be seen by reference to a typical McCabe-Thiele diagram (cf. Figs. 2 and 3). The operating lines have slopes of $L/(L + D)$ and $\bar{L}/(\bar{L} - B)$ above and below the feed respectively. For a fixed feed composition, and a given number of plates, it is seen that an increase of the slope of the operating line above the feed gives a purer top prouct, while the converse is true below the feed. Now, $L + D = V = \bar{L} - B$ if we ignore sensible heat losses and feed heat effects to avoid complicating the picture, and we can write:

Slope of upper line $= m = L/(L + D) = (V - D)/V$
(since V now $= \bar{V}$)

„ „ lower „ $= \bar{m} = L/(L - B) = (V + B)/V$

Furthermore, the intercept of the upper or enrichment operating line on the y-axis is given by $y_i = D \,.\, x_D/V$ and that of the lower or stripping line on the x-axis is $x_i = B \,.\, x_B/\bar{L}$.

Inspection shows that the slopes and intercepts of the operating lines jointly determine the end compositions and Fig. 4 illustrates how a change in feed composition can be countered by adjusting the controlling factors. The normal operating conditions are shown by dotted lines with a feed composition x_{F1}, and the new operating conditions to cope with a changed feed of composition x_{F2} to give an unchanged distillate composition x_D are indicated by unbroken lines. Here the slope of the operating line $(m = (V - D)/V = L/V)$ has been increased and the intercept factor D/V decreased. One way of effecting this would be by increasing V without changing D.

The modes in which slopes and intercepts affect the end products thus give a guide to control operation. Likewise they direct to the transient behaviour of a column. It should be noted here that the familiar forms of equilibrium diagrams, such as the McCabe-Thiele or Ponchon-Savarit, are based on steady state conditions and stoichiometric balances that do not obtain during transience. Typical conditions during change may possibly be as shown in Fig. 5, in which case the upper and lower parts of a column would desirably be considered separately in control design.

Control of a Fractionating Column

The criterion of operation of a distillation column is, of course, product analysis, but in the general case this can only be a secondary control because of the time factor. The functioning of a column is normally determined by the operating temperatures and pressures.

At a given pressure, the temperature of a given mixture of vapours in equilibrium with liquid is an indication of the composition and as a very rough approximation, temperature changes are proportional to composition changes.

Each particular system has its own characteristics, but these can be readily determined in the laboratory. A very simple case is given as illustration, but the principles apply to more complex systems.

The vapour pressures of benzene and toluene are plotted together against temperature in Fig. 6. Between them, vapour pressure curves of mixtures have been drawn. These are readily derived from the basic vapour pressure information. On any plate, as a first approximation, the mixture can be considered to be boiling and its composition relates to the local temperature and pressure in the column accordingly. The variation of temperature with composition of mixture can be followed from the curves. Very roughly, the order of change can be gauged from the overall difference and for benzene/toluene is $110.6 - 80.1 = 30.5°C$ over the 100% range. This is 0.3°C per 1% composition change. To maintain a plate composition within say 0.3% requires a temperature control difference of 0.1°C so that the control instrument should respond to 0.01°C.

The most difficult aspect of control of a distillation column is concerned with liquid hold-up. This means unduly long lag periods or slow response to disturbances. Operators of distillation columns will have experienced this. Because this is so, it would be desirable to control at three points, top, bottom and feed, to counter changes in conditions as soon as they can be detected (see Fig. 7). Any change in feed rate or composition will affect the feed plate composition in the first instance. An increase in temperature at that plate would indicate an excess of heavies requiring a preferential increase in reflux to compensate. Conversely, a decrease in temperature would indicate the reverse, a preferential increase in boil-up rate being required. Likewise, changes of temperature at the top and bottom plates (corrected for pressure, of course) would indicate corresponding changes in reflux or boil-up, which would be superimposed on the demand indicated by the feed plate control. With due respect to the inherent time lags in a column, speed of response of indicating instruments is less a requirement than sensitivity and accuracy combined with absence of zero drift.

It will now be useful to consider the functioning of each of the three controls mentioned, employing the simplifying assumptions stated earlier (cf. Fig. 2):

1. *The Reboiler*

The amount of heat put into the reboiler is controllable and determines V, the vapour rate. It also partly controls the quantity of bottom product as a difference between the downflow $\bar{L}$ and $\bar{V}$, if the level of the liquid in the reboiler is maintained constant. This latter is usually desirable for practical reasons, and any control applied to maintain this level constant is not regarded as part of the control of process conditions as such, but as an auxiliary control, which need not be considered further here. In brief, the operational control at the base of the column is normally the steam input. The higher the steam input, the less is the percentage of the more volatile constituents in the bottoms.

2. *The Feed*

The feed rate may or may not be a voluntary control. Where it is, reducing the rate can be a quick method of increasing the degree of separation and conversely.

3. *Reflux*

There are three main possibilities for top control:

(a) the offtake rate can be controlled—thus controlling the reflux by difference;

(b) the reflux rate can be controlled—controlling the offtake by difference; and

(c) the reflux/top-product ratio can be controlled by a proportioning device.

The net result of any of these is, however, the same, i.e.,

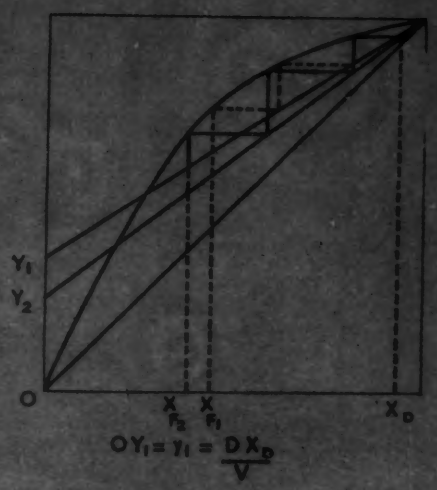


Fig. 4. Illustrating control of top product by reflux ratio.

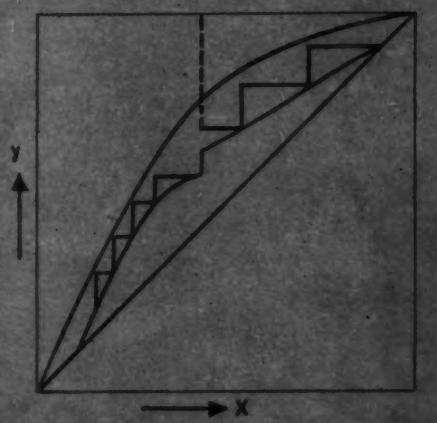


Fig. 5. Typical transient conditions in a fractionating column.

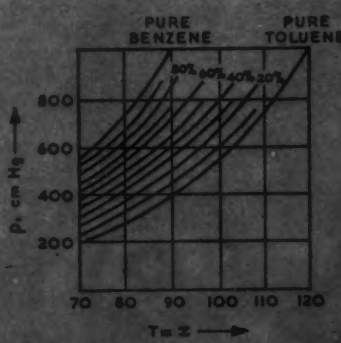


Fig. 6. Vapour-pressure curves of benzene, toluene and mixtures.

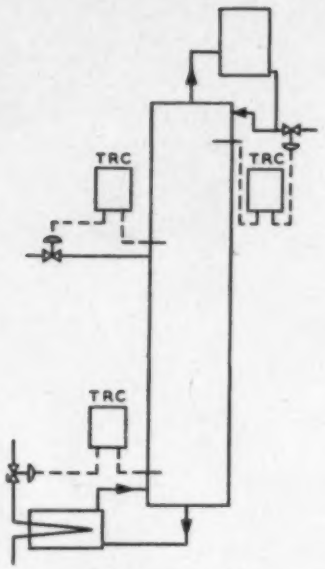


Fig. 7. One possible control arrangement for a fractionating column.

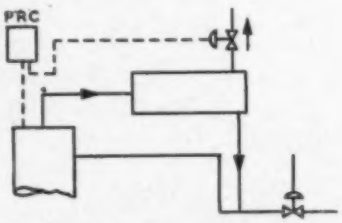


Fig. 8. Pressure control for column at above atmospheric pressure.

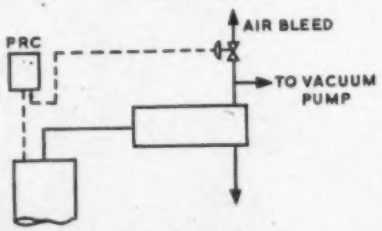


Fig. 9. Pressure control for column under vacuum.

a control of the amount of reflux returned to the column. The more the reflux, the purer the top product and the more overflow reaching the reboiler.

The effect of reducing the feed F is initially to reduce $\overline{L}$ and hence the ratio $\overline{L}/\overline{V}$ and the slope of the lower operating line. This results in more efficient stripping of light components so that the purity of the bottom product increases. The rising vapour is richer in lighter components and this in due course reflects in a purer top product. Control by feed rate, however, is not usually desirable for reasons outside the actual column operation and will not be considered further. Indeed, fractionating column controls are more often than not intended to counteract the effects of changes in feed rate as well as feed composition.

The main controls remaining are then steam input to the reboiler and the reflux. There are other possibilities but they are outside the scope of this paper.

The reboiler or steam input control reacts relatively quickly through the column as compared with the reflux control, since the vapour hold-up within the column is normally far less than that of the liquid, while the mass flow rates of both are of the same order. In the upper part of the column, therefore, both controls will be effective at an early part of any change, whereas in the lower part of the column the bottom control will have more weight in transient response.

The operational effect of these controls can be followed by considering an increase of steam input (V) while retaining the reflux control unchanged for each of the three possible forms of reflux control earlier described. To simplify the discussion, the feed will be assumed to remain constant.

(i) D fixed.

m is a fraction less than 1 and adding $\triangle V$ to both numerator and denominator of the fraction increases it. The top product hence becomes purer. Conversely, adding $\triangle V$ to both top and bottom of a fraction more than unity brings it closer to unity, i.e., makes it less. The bottom product likewise becomes purer, although this in any case must follow from the preceding consideration.

(ii) Reflux Rate (L) fixed so D increases.

Now slope m decreases so purity of distillate is less. Since D increases, B decreases, hence slope $\overline{m}$ decreases so the purity of the bottom product increases—as we have seen—at the expense of the purity of top product.

(iii) Fixed reflux ratio, i.e., L/D fixed.

Since L/D is fixed, the slope m is also fixed and the purity of the top product at first thought might seem to be unaffected. However, $D = V - L$ and it can readily be seen that a fixed reflux ratio control can lead to a bad top product, just as (ii).

In like manner, the effects of changing feed rate or composition, or a combination of changes can be predicted by considering how the slopes of the operating lines are affected together with the intercept points.

Auxiliary Controls

The auxiliary controls of a distillation column, although automatic, are outside the scope of this paper and will only briefly be mentioned. They include level control for the reboiler and controls for maintaining a correct degree of vacuum or pressure within the column (cf. Figs. 8 and 9).

Conclusion

The greater part of industrial fractionating involves multicomponent mixtures. The analytical treatment of the fractionating of such mixtures is sufficiently complex, even for steady state conditions, and omitting consideration that each component approaches equilibrium at its own rate. If, in addition, rate factors and system geometry have to be considered the difficulties facing theoretical treatment of transient response of such systems can be appreciated.

Some limited informative data can be obtained from columns under operation and a compilation and classification of such data could be valuable for design purposes. Because of the long time lags involved, however, and production requirements, the opportunities to study the response of industrial fractionating columns to input changes are relatively few. Scale-up involves uncertainties.

Automatic control nevertheless is being quite successfully operated on many distillation columns. The fundamental principles described in this paper indicate how such a control system can be designed. Sizing of control valves is linked with normal production requirements and expected disturbances.[1] Two term controllers (proportional plus reset) are usually adequate and the final adjustment of proportional band and reset rate to give optimum performance can be made when the column goes on stream.

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COST-ESTIMATING PROCESS INSTRUMENTS AND AUTOMATIC CONTROL EQUIPMENT

A number of methods of estimating the cost of instrumentation and automatic control equipment for a project are discussed.

by M. STOGENS

IN modern chemical plants instrument costs are a significant portion of the total investment costs and, therefore, must be estimated with increasing accuracy. In this article some methods are introduced for estimating instrument costs for chemical processes at the flowsheet stage. In the early days the control of such processes was effected only by checking the measuring instruments at intervals and recording the results on logsheets, with the operator taking the necessary action to maintain the desired process conditions. As time passed, more automation was applied and manual control was replaced by fully automatic control. It will be clear that such advances must be paid for and it is thus certain that future instrument costs will increase since the trend in modern plants is to use electronic rather than pneumatic controls. Furthermore, data-logging is now being introduced as well as the production of digital records leading up to computer-controlled systems. The most important of the several variables which have to be kept within certain limits are temperature, pressure, level and flow, all of which regulate conditions and quantities. In addition to these, there are the more expensive quality instruments such as the infra-red spectroscope and continuous refractometers. Below are listed several methods for estimating instrument costs.

First Method

This method expresses instrument costs as a percentage of the total installed equipment costs; thus for plants with:

(a) little or no automatic control = 5% of installed total equipment costs
(b) some automatic control = 10%; and
(c) centralised automatic control = 15%

Unless the user has considerable experience to guide him, this method of estimating instrument costs may give misleading results. W. Stanier (*Plant Engineering Handbook*, McGraw Hill, 1959, Section 16, p. 48) gives figures for various types of plant expressed as a percentage of total equipment costs (see top of following column).

Type of Process	% Equipment Cost
Ethylene plants	5
Solvent-dewaxing units	3.5
Thermofor catalytic cracking units	3.8
Viscose manufacture	3.2
Synthetic ammonia plants	3.4
Contact sulphuric acid plants	3.2
Nitric acid plants	2.6
Hydrochloric acid plants	2.0
Superphosphate plants	0.04
H.F. akylation units	6.0
Gas recovery plants	5.1
Styrene plants	5.0
Pharmaceutical plants	12–16
Soap plants	2–5
Electrolytic—non-ferrous—metal refining	0.91
Lime plants	0.45
Manufacture of fluoride salts	1.1
Pulp mills	3–4.5

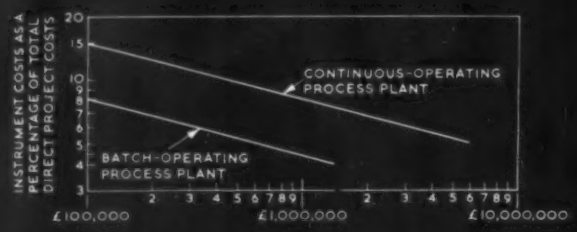
Second Method

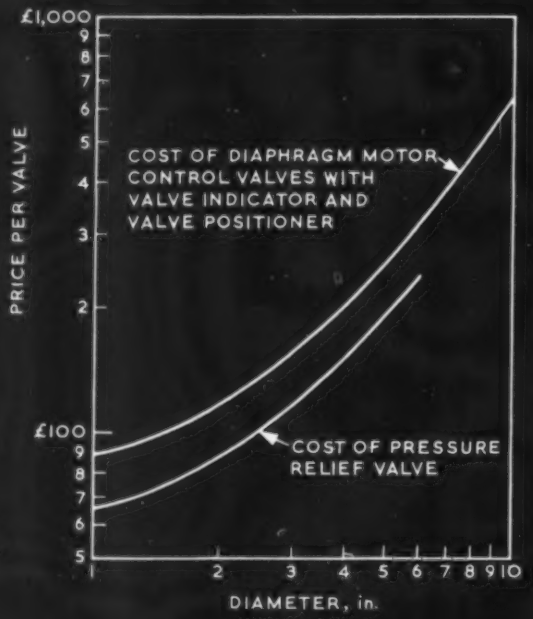
This method is based on the direct project costs. Percentages and direct project costs are given in Fig. 1. These figures give approximate ranges and must be handled with care. If possible, this method should be avoided, as costs for process and storage buildings will cause total direct project costs to rise steeply, but buildings will not affect instrumentation costs at all. From Fig. 1 it can be seen that there is a great difference in costs of instruments for batch and continuous processes. The main value of the graph illustrated in Fig. 1 is that it shows this difference. Otherwise it gives only an approximate idea of instrument costs.

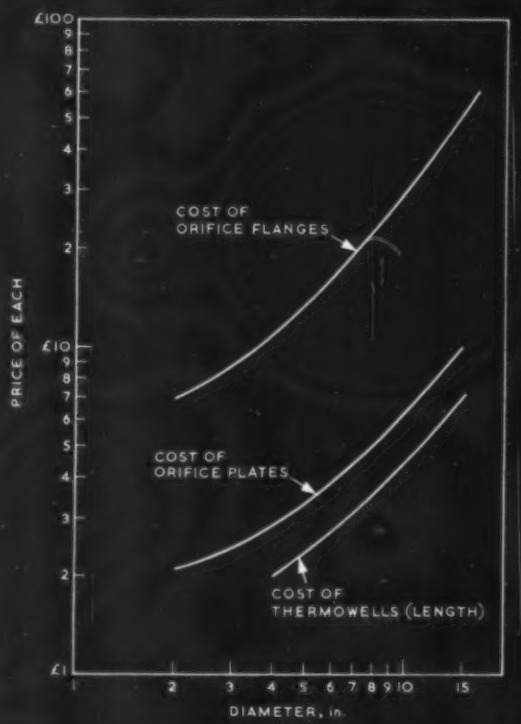
Third Method

With this method we obtain reasonable accuracy, as the free-on-board (f.o.b.) costs for instrumentation are determined as a percentage of the f.o.b. value for each type of equipment. Thus:

(a) distillation towers = 20%;
(b) process drums = 10%;
(c) heat-exchange equipment = 10%;
(d) centrifugal pumps = 10%;
(e) compressors = 8%;
(f) mixers = 8%;
(g) reactors = 20%;
(h) heaters and boilers = 5%; and
(i) extruders, centrifuges = 5%.


INSTRUMENT COSTS AS A PERCENTAGE OF TOTAL DIRECT PROJECT COSTS
CONTINUOUS-OPERATING PROCESS PLANT
BATCH-OPERATING PROCESS PLANT
£100,000
£1,000,000
£10,000,000


£1,000
PRICE PER VALVE
COST OF DIAPHRAGM MOTOR CONTROL VALVES WITH VALVE INDICATOR AND VALVE POSITIONER
£100
COST OF PRESSURE RELIEF VALVE
DIAMETER, in.


£100
PRICE OF EACH
COST OF ORIFICE FLANGES
£10
COST OF ORIFICE PLATES
COST OF THERMOWELLS (LENGTH)
£1
DIAMETER, in.

Indicator
Temperature indicator
Indicating controller
Level indicator
Indicator with alarm
Flow indicator
Pressure indicator
Recorder
Temperature recorder
Recording controller
Level recorder
Recorder with alarm
Flow recorder
Pressure recorder
Blind controller
Temperature controller
Blind alarm
Level controller
Pressure controller
Flow controller
Manual control valve
TW
Thermo well
Motor valve
Blind flange
Relief valve
SB
Spectacle blind
Reducing valve
FE
Flow element
Check valve
Spool
Globe valve
Sample cock
Pressure controller
Back pressure valve
TIC
Temperature indicating controller
LRC
Level recording controller
FRC-FA
Flow recording controller with alarm
TRC
Temperature recording controller

TABLE I

Add for each:	Number and Type of Instrument					This results in:	
	Flow	Level	Pressure	Temperature		total price instruments f.o.b.	total price instrumentation including installation and overhead
Heater	1 FRC 1 FR 1 FI		2 PR	1 TRC 2 TR 2 TI		£ 1965	£ 6500
Distillation tower	2 FRC 2 FI	1 LG 1 LC	2 PI 1 PRC	5 TI 2 TRC		2850	9500
Heat exchanger			1 PI	2 TI		25	85
Pump			1 PI			6	20
Compressor	1 FI		2 PI	2 TI		80	270
Process vessel		1 LC 1 LG	1 PI	1 TI		285	950

TABLE II—COSTS OF INSTRUMENTS AND CONTROLLERS

A. Complete instruments and controllers. All controllers include costs for one 1½-in. control valve with valve-positioner.

Flow instruments		£
FI	Flow indicator-rotameter	50
FI	Flow indicator-orifice	100
FG	Gauge glass	20
FR	Flow recorder	225
FR	Flow recorder-rotameter	260
FC	Flow controller	300
FRC	Flow recorder controller	450
FIC	Flow indicating controller	425

Level instruments		£
LG	Level gauge—15-in.	20
	30-in.	30
	45-in.	40
LI	Level indicator	125
LC	Level controller	240
LR	Level recorder	180
LRC	Level recorder controller	450
LA	Level alarm	110

Pressure instruments		£
PI	Pressure indicator (standard)	6
PI	Pressure indicator (chem. type)	25
PR	Pressure recorder	135
PRC	Pressure recorder controller	430
PQ	Pressure regulator	15
PC	Pressure controller (bourdon)	150
PIC	Pressure ind. contr. (prop. and integral-narrow band)	175

Temperature instruments		£
TI	Temperature indicator	10
TI	Temp. ind.-multipoint—10 points	250
	20 ,,	350
	30 ,,	450
TC	Temperature controller	200
TR	Temperature recorder	200
TRC	Temp. recorder controller	500

B. Parts of Instruments	£
Recording receiver controller	200
d/p cell transmitter	120
Indicating receiver	15
Recording two-pen receiver	110
Switch—sequential signal	30
Switch—electric-level	75
Air set	3
Alarm set	30
Valve positioner	30
Displ. type level controller/transmitter with prop. control—14-in.	120
32-in.	150
72-in.	200
Electronic strip chart rec. potentiometer	350
Radio transmitter/receiver	700

*C. Analytical instruments**	£
*p*H-indicator	200
*p*H-recorder	400
*p*H-recorder/controller	500
Gas/liquid chromatography+column recorder	1500
Continuous refractometer and recorder	1500
Catharometer	1000
H_2S recorder	1500
Photocell glass	350
Gravity recorder	300
Gravity recorder controller	450

* These figures are approximate only.

TABLE III—NUMBERS AND TYPES OF INSTRUMENT REQUIRED AT A CHEMICAL PLANT

Type of Unit	Flow	Level	Pressure	Temperature
Heater	1 Flow rec. controller 1 Flow rec. 1 Flow ind.		2 Press. contr.	1 Temp. rec. contr. 2 Temp. rec. 2 Temp. ind.
Distillation tower	2 Flow rec. controllers 2 Flow ind.	1 Level gauge 1 Level contr.	2 Press. ind. 1 Press. rec. controller	5 Temp. ind. 2 Temp. rec. contr.
Heat exchange equipment			1 Press. ind.	2 Temp. ind.
Pump			1 Press. ind.	
Compressor	1 Flow ind.		2 Press. ind.	2 Temp. ind.
Process vessel		1 Level contr. 1 Level gauge	1 Press. ind.	1 Temp. ind.

This list gives a rough indication of the number and type of instrument which can be used for estimating purposes when the instruments are not specified on the flow-sheet or in the equipment list. For each instrument with a controller one control valve must be added. The prices for these valves depend on size and material.

When this method is used it must be borne in mind that equipment costs for small plants is low and conversely for large plants. But the prices of the main instruments, e.g., transmitters, indicators, receivers and recorders, are standard and do not vary much with the size of the plant. In the case of small process plant, only the instrument piping, electric wiring and, particularly, the control valves cost less than they do in the case of the larger process plant. In pilot plants, for example, the equipment is usually very small. There is a considerable amount of instrumentation; consequently, the instrument costs are a very high proportion of the total cost. It is not unusual for 50% or so of the total investment in such cases to be devoted to instrumentation and control, mainly because variables are often measured at a host of points which would not be of interest once the large-scale unit has been developed. In this method we express instrument costs as a percentage from the f.o.b. value of the process equipment, so this method only gives the f.o.b. prices of the instruments, including control valves, piping, wiring, and so on. Costs for installation and overheads must be added (these costs will be handled in the fifth method).

Fourth Method

This is a more realistic method with greater accuracy than the first three. In this method, for each number and type of process equipment a certain number and type of instrument are added.

Clearly, the actual number and type of instrument that will be applied depends on many factors. Every company has its own instrumentation plans and control systems; one may prefer manual control and another fully automatic control. One firm may instrument as simply as possible, another may prefer "gold-plated" units. Also, every process requires additionally its own controllability. Processes involving distillation are recognised heavy users of instruments. A fractionating column may require a potentiometer to control column temperature by resetting the control index of a flow controller, the steam supply to the reboiler, a flow controller on the tower feed, a liquid level controller at the tower bottom and at the reflux accumulator, a flow controller on the reflux line and integrating flowmeters on the product lines. Processes involving mixing, filtering and crushing, on the other hand, require only the simplest form of instrumentation. Nevertheless, this method is based on practical experience and provides reasonable answers. The results in the last column of Table I show how much must be allowed for each number and type of process equipment. Thus for a heater the f.o.b. price of the main instruments, including 1½-in. control valve with positioner, is £1965. The total price including piping, wiring share for the control room, etc., will be £6500.

Apart from their utility for instrument cost estimation, these figures show that instruments are an appreciable proportion of the total cost of the plant. It is well known that the cost of instrumentation sometimes even exceeds the cost of the process equipment itself.

All the above-mentioned methods are useful for estimating instrument costs quickly particularly when the chemical engineer has little or no time to specify the instruments on the flowsheet or on the list of equipment. However, since instrument costs are very important, greater accuracy than that offered by the fourth method can be obtained when necessary by applying the procedure used in the:

Fifth Method

This method enables us to estimate with accuracy when we know the number and type of instruments required for the process. Table II lists the prices of instruments normally used in the chemical industry.

TABLE IV

Costs of main instrument	100%
Additional pipework	20%
Electric wiring	20%
Control room, with ancillary foundations, site work and paving	15%
Steel structures, painting, cleaning, temporary facilities and miscellaneous items	15%
Total materials	170%
Total installation costs, particularly instrument pipework and wiring	80%
Total materials and installation costs	250%
All indirect costs (engineering, drafting, processing, purchasing, administration, expediting, general overheads, etc).	80%
	330%

In this table all controllers include one 1½-in. control valve with indicator and valve positioner. The prices of control valves of other sizes can be obtained from the graph given in Fig. 2. In Fig. 3. a graph is given from which the prices for orifice plates, orifice flanges and thermowells can deduced. The fact that the flowsheet usually shows the instrument wiring by dotted lines should not lead the estimator to conclude that the cost of wiring is insignificant. Installation of instruments and particularly instrument piping and wiring at the entry to the control room requires highly skilled labour.

Once the prices of the complete process instruments are known, considerable allowances must be made for additional materials, labour and overheads as shown in Table IV.

From this final result it can be seen that when the f.o.b. price of the main instruments is known, the figure obtained will have to be multiplied by an average of 3.3 to obtain the total installation costs. Although the total costs so obtained by this method may appear high, they are in fact confirmed by experience. Cost estimation, of course, is not an exact science, as, in reality, figures differ and depend on many factors.

This list gives a rough indication of the number and type of instrument which can be used for estimation purposes when the instruments are not specified upon the flowsheet or in the equipment list. For each instrument with a controller must be added one control valve. The prices for these valves depend on size and material.

Hydrorefining of Benzoles

FINAL design of commercial units for the hydro-refining of benzoles has been announced by Newton Chambers & Co. Ltd. Mr. R. Middleton informs us that, in addition to benzoles, different types of naphtha have been treated in the pilot plant and the results have been extremely successful, giving colour-stable, sweetly-smelling naphthas in the boiling range of 160°C to 230°C by hydro-refining with coal gas at working pressures of the order of 500 psi. Sulphur content was reduced from the order of 0.7% w/w down to 0.05% w/w, while the Bromine Number was reduced from the order of 50 gm/100 gm to below 0.1 gm/100 gm. A commercial-sized pilot plant for the production of pure benzene by crystallisation has now been constructed and commercial units based on this process are being offered. The firm also state that a joint programme of work on the crystallisation process has been completed during the past year in conjunction with Benzole Producers Ltd. and the Coal Tar Research Association, the results of which will be published shortly to the benzole industry.

681.121.8; 66-498.4

FLOW MEASUREMENT OF A HIGH-TEMPERATURE FLUID WITH A VENTURI METER

The development of a method for measuring the differential pressure produced by the flow of molten sodium at 750°F through a venturi meter

by R. C. CAIRNS, B.Sc., Ph.D., and P. FISHER, B.Sc.

ELECTROMAGNETIC flowmeters have been used, almost universally, for the measurement of flowrate of liquid metals. These flowmeters, however, suffer from the disadvantage that their e.m.f.-flowrate relationship is dependent on such variables as the temperature effect on the electrical resistivities of the liquid metal and pipe wall, conduction of the generated e.m.f. along the walls of the pipe, magnetic field variations and the temperature effect on the magnetic properties of the magnet.[1] Furthermore, the derivation and application of some of the theoretical correction factors used to allow for these variables, when doing accurate work, is obscure.[2]

For these reasons, it is always advisable to calibrate E.M. flowmeters against some absolute method of measurement. According to HALL and CROFTS,[3] the actual e.m.f. obtained in practice is about 80% of the predicted value, based on ELROD'S theory.[4]

The calibration equipment may consist of calibration tanks or some differential pressure device. Calibration tanks are cumbersome, expensive and can be used only over a limited flow range. Differential pressure flowmeters such as orifice plates, nozzles or venturis all have the disadvantage that in the past it has been extremely difficult to measure and calibrate accurately for a liquid metal the differential pressure between the tappings.

The method of flow measurement described here, and used for sodium at 750°F, involves the use of a stainless-steel diaphragm on each leg of a venturi. The diaphragm movement regulates air flow from a small nozzle and the back pressure built up indicates the static pressure of the sodium. Connection of the output pressures of the diaphragms to a mercury manometer gives the pressure difference across the venturi, and hence the flowrate. The differential pressure can be fed also to a differential pressure transmitter and recorder if required.

Description of Apparatus

The system diagram is given in Fig. 1 and the actual diaphragms mounted over the venturi are shown in Fig. 2. A cross-section of a diaphragm unit is given in Fig. 3. The diaphragm assemblies were 229RF liquid level transmitters obtained from TAYLOR INSTRUMENT COMPANIES OF AUSTRALIA LTD. and were modified for use on a sodium loop

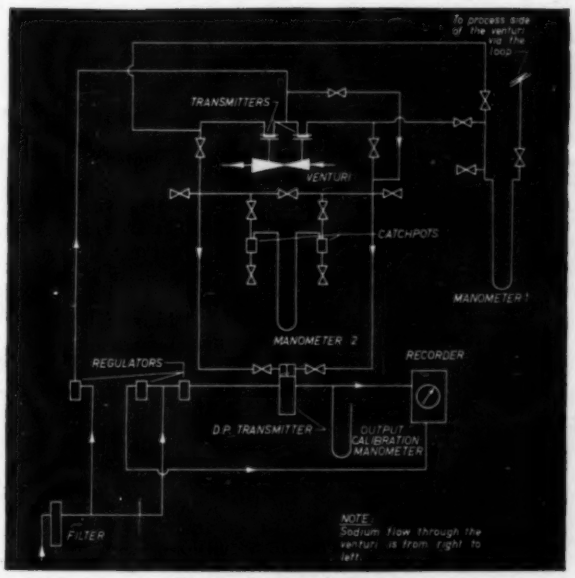
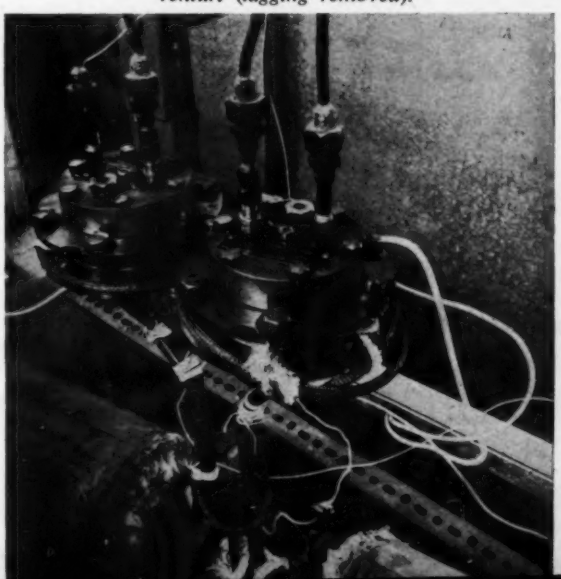


Fig. 1. System diagram.

Fig. 2. View of the diaphragms mounted over the venturi (lagging removed).



Dr. Cairns *is at present attached to Atomic Energy of Canada Ltd., Deep River, Ontario, Canada, on a two-year posting from the Australian Atomic Energy Commission.* **Mr. Fisher** *was attached to the A.A.E.C., but has since returned to industry.*

described elsewhere.[5] The diaphragm was made from type 316 stainless steel and was 0.005 in. thick.

A venturi meter was selected for use because this gives minimum pressure loss and the meter is completely drainable. In venturis, particularly those of small throat diameter, the discharge coefficient can be influenced by any roughness of the inner surfaces or sharpness of edges. Although the venturi used was smooth machined and examined for imperfections after manufacture, it was necessary to determine the discharge coefficients over the Reynolds number range intended for the sodium.

The venturi, machined in one piece from 18/8/Ti stainless steel, was designed according to the A.S.M.E. publication on fluid meters.[6] The upstream and downstream diameters were fixed by the 1-in. o.d. × 16 S.W.G. tube used either side of the venturi. The ratio of throat diameter to upstream diameter, β, was selected to give almost 200 in. w.g. pressure differential for the maximum sodium flow of 10 gpm at 932°F with the venturi at 750°F. Upstream and throat pressure tapping holes were $\frac{3}{32}$ in. diam.

The A.S.M.E. data were used to design the venturi, since the British Standard Code on Flow Measurement,[7] at present being revised, does not cover venturi meters for pipe sizes less than 2 in., whereas discharge coefficients are available in Reference 6 for HERSCHEL design venturi tubes as small as $\frac{1}{2}$ in. × $\frac{1}{4}$ in.

These discharge coefficients were experimentally verified, before using the venturi meter on the sodium loop, with clean water as the flowing liquid.[8] Throat Reynolds numbers up to 298,000 were used, the maximum value for the sodium flow, and Fig. 4 shows the experimental coefficients of discharge plotted against Reynolds number. The broken line above a Reynolds number of 150,000 is an extrapolation of the A.S.M.E. line. Agreement throughout is good.

The diaphragm assemblies, venturi and the interconnecting pipework were trace heated and lagged in position on the sodium loop. A thermocouple was strapped to the body of each assembly and to the venturi meter. The assembly is basically a non-indicating pressure transmitter employing a 1:1 stainless-steel diaphragm.

In operation, air continually enters through the inlet and leaves through the exhaust and output lines (Fig. 3). The movement of the diaphragm caused by a change in process pressure shifts the baffle with respect to the nozzle of the exhaust outlet. An increase in process pressure moves the baffle closer to the nozzle, giving an increase in output pressure. During operation the transmitters are supplied with filtered air at 50 psig. The output of each transmitter is connected to a single air-mercury manometer and a differential pressure transmitter and recorder. These instruments were located at the control panel of the sodium loop as shown in Fig. 5, and were approximately 40 ft from the diaphragms and venturi.

It is interesting to note that a differential pressure transmitter, developed at Harwell[9] for direct connection to a differential pressure producing device, is favoured for flow measurement of molten bismuth. However, with this type of instrument it is not possible to calibrate and check the calibration *in situ* in a system, since it would be necessary to measure the differential pressure that is required to operate the transmitter, by some other method. For liquids whose corrosive or hazardous nature is such that no unwelded flanges are permitted in a liquid stream, it is almost essential to use apparatus which will enable calibrations to be made without removing the equipment from the system.

An experimental evaluation of high-temperature pressure transmitters has been carried out at Oak Ridge National Laboratory.[10] This work was directed towards obtaining an instrument which would give minimum zero shift and maximum accuracy over the full range of process pressures of 0-100 psig and process temperatures of ambient −1500°F.

The details of the method of calibration used when some of the units were placed in liquid metal loops for corrosion

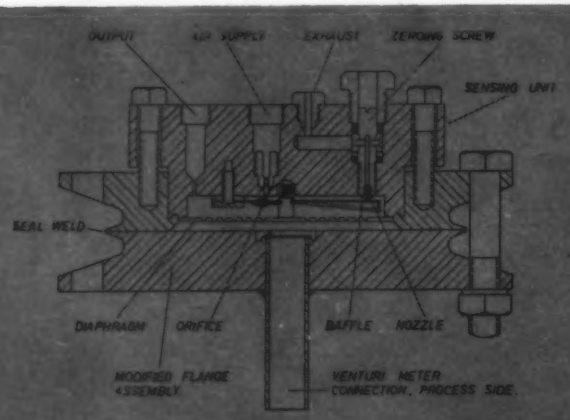


Fig. 3.

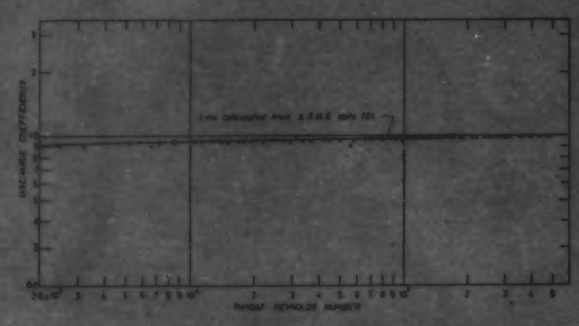


Fig. 4.

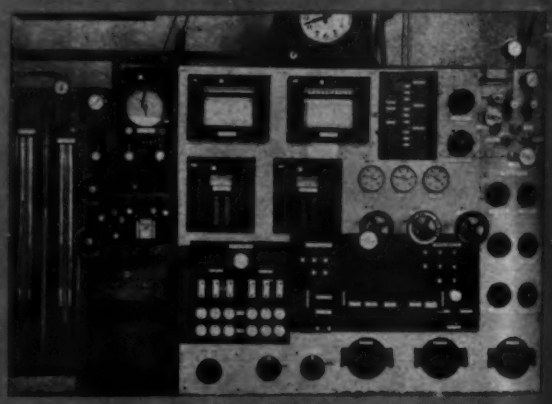


Fig. 5.

Fig. 3. Cross-section of a diaphragm unit.

Fig. 4. Discharge coefficients for the venturi meter.

Fig. 5. Control panel of the sodium loop. (Manometers, D.P. transmitter and recorder at left).

Fig. 6. Initial calibration results with air.

Fig. 7. Calculated flowrate versus pressure drop for the venturi.

tests are not given. There appears to have been no attempt made to devise a method of calibration to correct for zero shift or temperature effects. The instruments tested featured 0.025-in.-thick non-removable diaphragms or bellows which make the accurate measurement of low differential pressures difficult.

Calibration

Before installation the transmitters were tested and set so that they operated over the differential pressure range required. Each transmitter was first set to zero by applying a known air pressure on the process side and comparing this with the indicated pressure on the output side, as measured on a mercury manometer. With an air supply of 50 psig to the instrument, it was found possible to adjust each transmitter, in the normal way, to give linear outputs agreeing to within 1-2% of the process pressure between 4 and 30 psig.

A circuit was then set up to compare at room temperature the output differentials from the transmitters with known differentials applied between the process sides of the transmitters. Fig. 6 shows the results of this initial calibration.

The output differentials differed from the input differential when the process pressure on the low-side transmitter exceeded 22 psig. The maximum differential applied was 16 in. of mercury, which means that the instruments functioned correctly up to 30 psig applied to the high-side transmitter.

The transmitters were installed on the loop, as shown in Fig. 2, by welding the venturi meter connection of the transmitters direct to the venturi meter tappings. The transmitters were placed above the venturi so that sodium could drain from the tappings during shutdown.

As mounted on the loop and with the system arrangement as shown in Fig. 1, it is possible to check the output of each transmitter individually against the loop pressure, all pressures being accurately measured by mercury manometers. At the same time the outputs from each transmitter can be compared on a single mercury manometer.

When it is necessary to check the calibration of the assembly after circulating sodium, the pumps are stopped and the loop is drained to below the level of the venturi meter, thus avoiding circulation by thermal convection.

The gas pressure at the venturi is varied by means of the loop vent and nitrogen valves. Manometer 1 (Fig. 1) is used to indicate the pressure difference between the loop pressure (process pressure) and the output of either transmitter. Simultaneously, the outputs of both transmitters may be compared on manometer 2.

In this way it has been possible to calibrate the assembly *in situ* to give output readings accurate to within 1.5% of the loop design flowrate (5000 lb./hr) over the range of 4 to 30 psig at the venturi inlet.

Operation

The sensing unit of the transmitter at present used is made of brass. Normal operational temperature at the transmitters, with sodium in the venturi flowing at 750°F, is 550°F, and at this temperature performance has been good. With stainless-steel sensing units, higher temperatures could be tolerated. The response to changes in flowrate have been immediate at the manometers.

No difficulties have been experienced with plugging of the pressure tappings. In the event of a diaphragm or internal component of the transmitters being damaged, it can be replaced without removing the complete assembly from the loop.

Fig. 7 gives the calculated flowrate versus deflection curves for sodium in the venturi used. These curves have been based on the discharge coefficients from Fig. 4 and the following equation from Reference 6:

$$w = 358.9 \left(\frac{C D_2^2}{\sqrt{1 - \beta^4}} \right) \sqrt{\rho h_w}$$

where w = flowrate, lb./hr;
C = coefficient of discharge;
$\beta = D_2/D_1$;
D_2 = throat diameter, 0.376 in.;
D_1 = upstream diameter, 0.873 in.;
ρ = density of sodium at line temperature, lb./cu. ft; and
h_w = differential, in. of water at 68°F.

The outputs from the two transmitters have been connected also to a pneumatically operated differential pressure transmitter and recorder as well as to the mercury manometer system. This has been done for convenience to provide a continuous record of the flowrate.

Conclusion

The flow measurement system described here and used on a sodium circuit has been found to be reliable, easy to use and the results have been reproducible. It is independent of temperature up to 550°F at the transmitters, which is equal to a measured temperature of 750°F at the venturi.

ACKNOWLEDGMENT

Acknowledgment is due to Mr. M. J. Barrett, who assisted with the experimental work.

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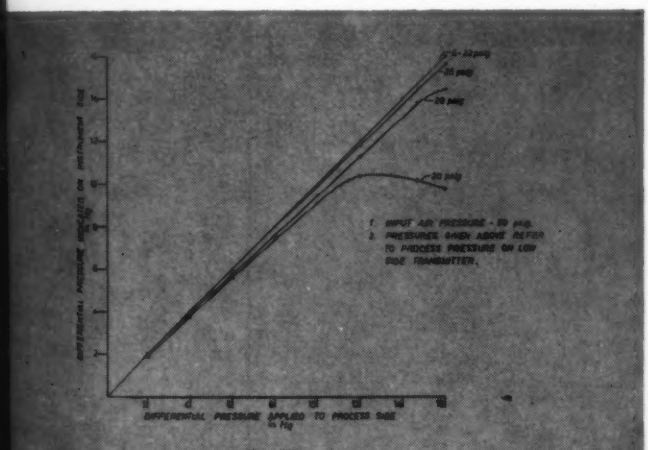

Fig. 6.

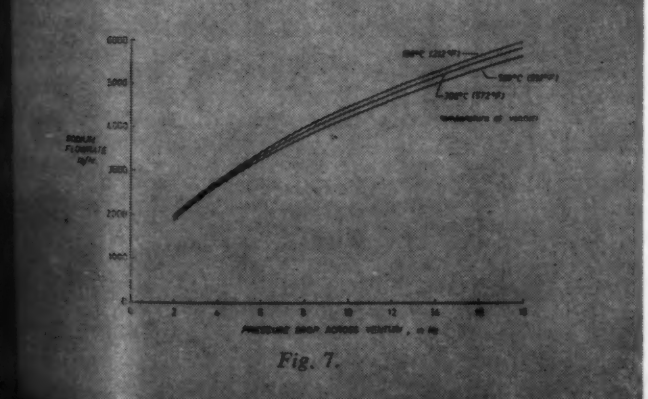

Fig. 7.

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SELF-ADAPTIVE CONTROL SYSTEMS

The distinctive feature of these systems is that the machine "notes" the response to a control action, then carries out a further action. This is repeated until the desired response is attained.

by N. W. REES, B.Sc.

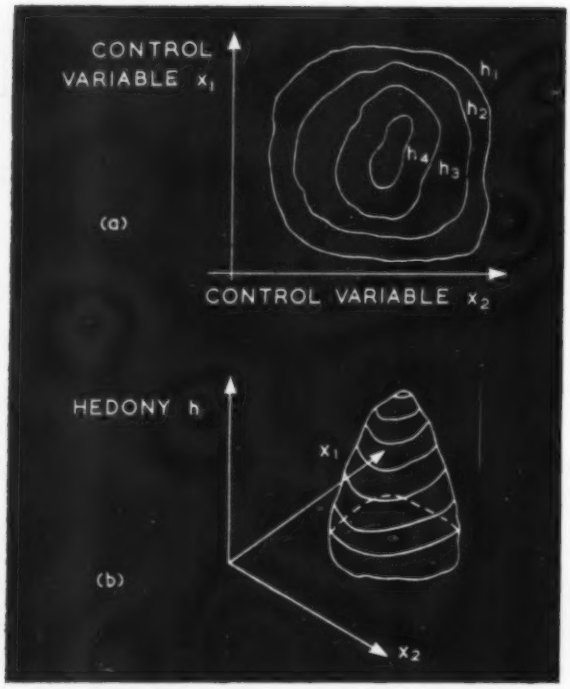

Fig. 1. Graphical representation of the functional relationship of Equation (1) *for two control variables.*

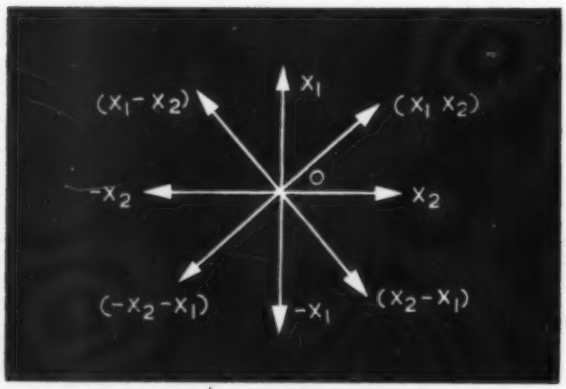

Fig. 2. Possible control actions that can be made from any point O.

THIS paper is mainly devoted to research which is being carried out at the University College of Swansea on self-optimising control systems using sampled data. Although the work is primarily concerned with the chemical industry, the computer that is being constructed is capable of self-optimising more general systems. The research is being carried out under the auspices of D.S.I.R.

A typical system is one which is represented by a functional relationship of the form

$$\eta = \varphi(x_1, x_2, \ldots x_n) \qquad \ldots . (1)$$

where η is the response (e.g., yield) and $x_1, x_2, \ldots x_n$ are the variables of the system.

Generally the n-variables fall into three categories:

(a) those that are under the control of the human operator or the computer. These will be called "control variables";

(b) those that are preset by the operator and remain constant thereafter. These will be called "controlled variables"; and

(c) those that cannot be controlled or predicted, such as noise in electrical systems. These will be called "uncontrolled variables".

It is required of the computer to adjust the control variables so that for all variations of the uncontrolled variables some aspect of the response η (for example, constant η; max. η) is satisfied. The only information that the computer receives is the control action and the effect of this action.

The problem now being studied at Swansea is a particular case of Equation (1). In the problem we regard x_1 and x_2 as control variables, $x_3 \ldots x_j$ as controlled variables and $x_k \ldots x_n$ as uncontrolled variables. This makes the problem three dimensional. The three dimensions are: control variable (x_1), control variable (x_2) and the degree of achievement (or hedony) h.

If we fix $x_3 \ldots x_j$ and then imagine $x_k \ldots x_n$ as being constant we obtain a graphical representation of the process as shown in Fig. 1. The effect of variations in $x_k \ldots x_n$ is to move the h contours relative to the x_1x_2 axes—which, of course, alters the maximum. Although Equation (1) tells us that contours like those shown in Fig. 1 exist, their exact position and shape is unknown. It is this fact that makes a searching technique within the bounds of x_1 and x_2 necessary.

Neville W. Rees *was educated at the Bishop Gore Grammar School, Swansea, and the University College, graduating in* 1957 *with an Honours Degree in Mechanical Engineering. Since* 1957 *he has been studying for a Ph.D. degree at the College, working partly at the B.P. Refinery, Llandarcy, and in close collaboration with the Control Mechanisms and Electronics Division of the National Physical Laboratory.*

Having replaced the physical system by the systems of Fig. 1, the problem can be simply stated with reference to Fig. 1. Starting from any point O devise a technique for climbing a hill H, which is known to exist in the vicinity of O. Having reached the summit of the hill, remain there until due to external circumstances the position of the summit changes—then start searching again for the new summit.

The computer that is being constructed at Swansea attempts to solve this problem. Four different methods of solution are embodied in the same computer.

For all methods the basic working principle is the same. A control action (such as movement of one or more dials or knobs) is made, and after a period of time, dependent on the dynamic characteristics of the plant, the effect of this movement on response is noted—then another control action is made. Eight possible control actions are allowed and these are shown diagrammatically in Fig. 2. In this figure all steps have the same size, but this is not necessary in the actual process, as will be shown later.

The four methods differ in the way in which the control action is selected. In some methods this is done at random, whilst in others rules are devised for the selection. Each of the four methods of solution embodied in the computer is outlined below.

Method 1

This is shown in Fig. 3. At O a random step is chosen from the eight possible steps. This takes the system to state O_1. If this step is found to be successful, that is, it has improved the system, new random trials are made about O_1. It is obvious that the computer must not be allowed to pick on the step that would return it to its previous state O and so step O_1O is omitted from the eight possible steps. If the new step is unsuccessful, e.g., O_1 to O_2, the system is returned to its former state O_1 before further random steps are made. Note that this time steps O_1O and O_1O_2 have to be omitted from the eight possible steps. If the step chosen at O_1 is successful, the above procedure is repeated at O_3.

The system will detect the summit by the fact that any move made from the summit must decrease performance; this is true regardless of what method of hill-climbing is being used. At the summit the system is constantly monitoring itself in order to detect any change in summit.

Method 2

This method is an extension of Method 1, and is illustrated in Fig. 4. Here the first move made, taking the process from state O to O_7, is unsuccessful and so the process is returned to O before further random trials are made. The next step tried, O to O_1, is successful and so this control action is repeated taking the process to state O_2. Thus in this method repetition of a good move replaces the random trials that were previously used. This successful action is carried on until it no longer is the successful action, in this example, the step from O_5 to O_6. Here the first action again is to return to the previous successful state before making random trials about that state. At O_5, for example, O_9 is a worse state but O_9 is better, so the control action that took the system from state O_5 to O_9 is continued. This technique is repeated until the summit is reached.

Method 3

This method is very similar to the method of steepest ascent, and is shown in Fig. 5. At O all eight possible actions are tried in sequence. The effect on performance of each action is noted and the action which gives the best performance is determined. This direction is then moved along in steps until a step becomes unsuccessful. The unsuccessful step is retraced and then the whole process which was carried out at O is repeated at O_1 and so on.

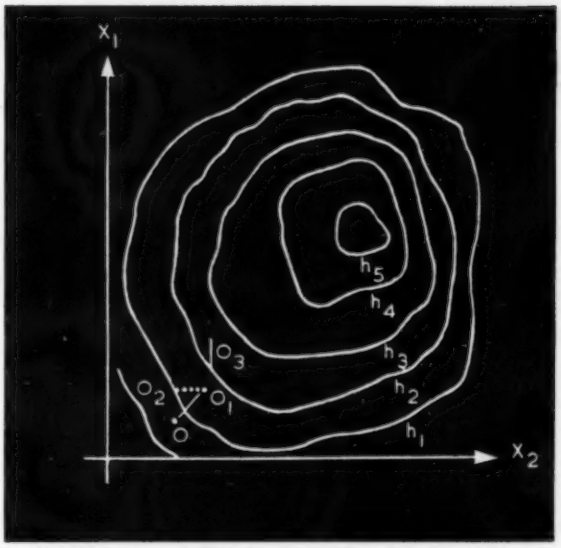

Fig. 3. Illustration of Method 1.

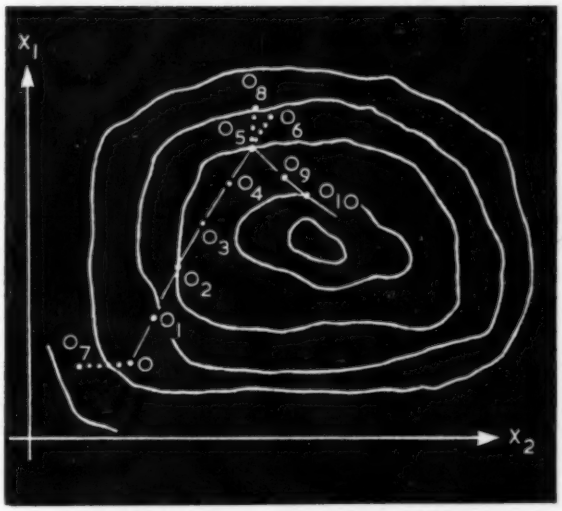

Fig. 4. Illustration of Method 2.

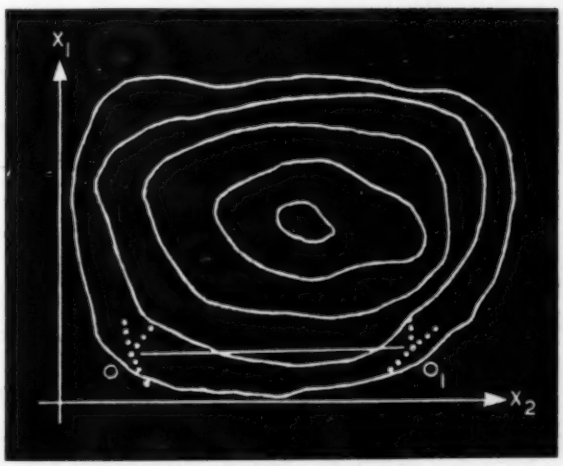

Fig. 5. Illustration of Method 3.

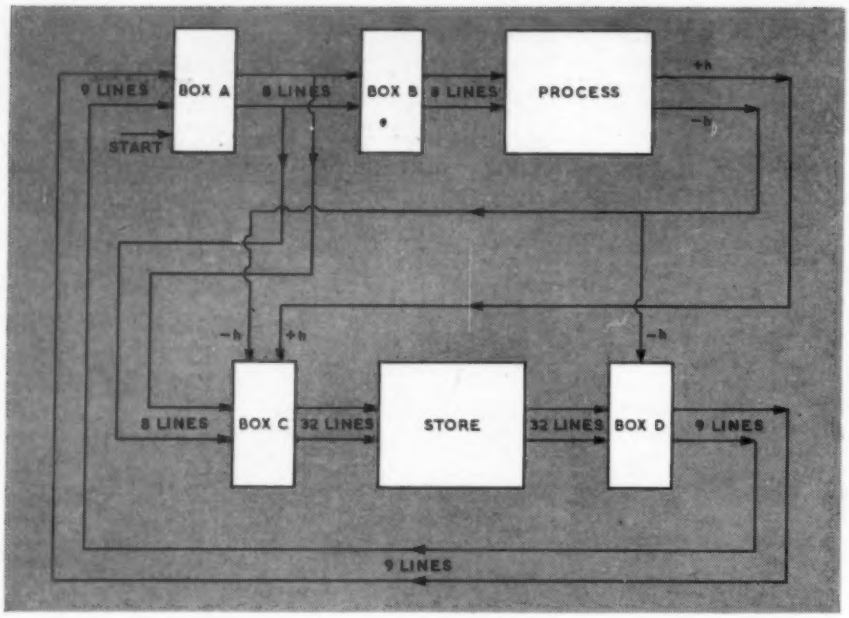

Fig. 7. Block diagram of the system employing Method 4.

FUNCTION OF THE BOXES

Box A generates control actions that are dependent on the output of Box D.

Box B performs the operation of repeating the adverse step. Triggered by a −h signal.

Box C controls the input to the store. Information is sent to different parts of the store depending on whether the control signal to Box C is +h or −h. Also depending on these parameters is the function that the input has in the store.

Box D controls the output of the store. The store output is either a suggested control action or a no-information signal. The no-information signal causes Box A to generate a random control action; any other signal causes Box A to generate the suggested control action. The output is trigged by −h.

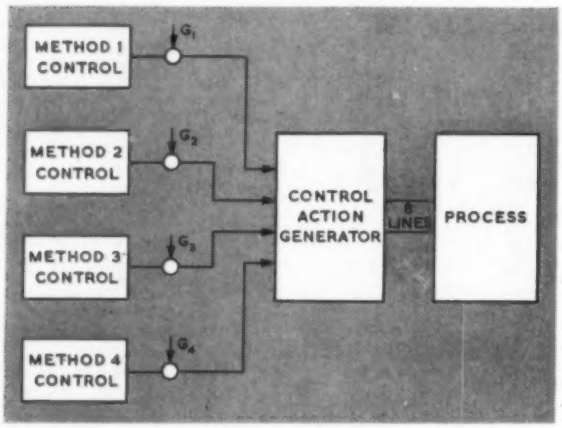

Fig. 6. Schematic block diagram of system.

Method 4

This method is a refinement of Method 2. It incorporates all the principles of Method 2 and also includes a short memory store. The store allows the use of a limited amount of past experience. When, at such a point as O_5 in Fig. 4, the computer would normally randomly search for a new successful move, the store will now first be searched to see if it contains any information from past experience relevant to this new situation. If this is the case, the information is given priority over the random searching technique, but otherwise random searching takes place.

How the information is put into the store, what form it takes in the store, how it is erased and how best use is made of it cannot be discussed in a synopsis of this nature. It is sufficient to say that by this method it is hoped to improve considerably on the performance of Method 2.

A block diagram of the complete system is shown in Fig. 6. In it the hedony signal completes the feedback loop. Fig. 7 illustrates the system for Method 4.

The hedony transducer and the control action generator are common to all methods. The hedony transducer needs only to transmit hedony increased or hedony decreased. However, the behaviour of the control action generator depends on which of the four methods is being employed. Each technique can be easily made to take command by closing the requisite gate ($G_1 \ldots G_4$). The size of control action to be made can also be introduced into the problem. The simplest case has only one step size, but this case and that using only two steps—large and small—can lead to trouble near the optimum. The ideal is to have some sort of proportional step size. The present system uses three sizes of step. Step size control is not shown in Figs. 6 and 7.

What has been outlined for three dimensions can in theory easily be developed to n-dimensions involving n-1 controllers. However, there are obvious complications arising from the multiplicity of dimensions. Perhaps the most important is the time element, that is, how long does it take to get to the summit. There appear to be ways, however, by which this difficulty can be alleviated, the most obvious of which is a more efficient use of the system information. After completing an investigation of the possibilities outlined here, I intend to try some of these further techniques for the more efficient use of information on the two-dimensional problem.

Fuel-Cell-Powered Tractor

In 1958 the American company Allis-Chalmers disclosed that it had made important steps in the development of fuel cells. In October, 1959, a practical field demonstration at West Allis, America, of an experimental fuel cell powering a research tractor was given by the company. The fuel cell system used in the tractor is believed to be the largest ever built so far and the first self-contained system ever used to power a vehicle. The cell system consists of 1008 fuel cells joined together into 112 units of nine cells each arranged in four banks. A mixture of gases is fed into the cells under pressure and causes a reaction in an electrolyte. This causes a direct current to flow to a 20-hp electric motor which acts as the tractor's automotive power unit. Other uses envisaged for these cells are for electrochemical processes, such as platforming, electrolytic cleaning and electrolytic refining of metals.

GRANULATING FERTILISERS —NOW AND IN THE FUTURE

IN Europe the most usual method of granulating compounded fertilisers is to dry mix the ingredients, agglomerate the mixture with a small amount of added water and/or steam in a pan, inclined disc or drum granulator, then dry and screen the resultant product. The relatively small amounts of fines and crushed oversize are returned. At the Technical Meetings of the International Superphosphate Manufacturers' Association, M. GIORGINI* and WM. C. WEBER pointed out the basic disadvantages of this method. It does not start from the primary raw materials; the processing must be done separately in advance, while considerable rehandling and storage of intermediates is involved. The authors recommended a fundamental approach to the problem in the general form of a "slurry process" starting from the basic phosphate and nitrogen raw materials. The slurry together with an added source of potash will then be used directly in a granulating system. A complete plant will consequently then consist of only stores for salts, ammonia and acid, a granulating plant and product storage and shipping. No intermediate processing, curing or rehandling will be required.

M. GIORGINI claimed that his own proposals represented "a long step forward in the search" for such a process. There is no room here to describe them extensively, but a special feature, the "heart" of the process, is the blunger—a powerful double-shaft trough paddle mixer. In this, the trough and interlocking paddle shafts are set at a steep angle. The shafts operate at high speed in opposite directions so that the blades descend at the sides and rise, intermeshing in the centre. The tank sides open up to permit easy cleaning.

Granulated and dry salts are fed into the upper part of the machine and between the shafts. The intermeshing blades rising rapidly through this mass tend to keep the solids in very active suspension so that, in effect, a fluidised bed of granules flows down the centre of the machine. At the same time the granules overflow the shafts laterally and are pushed into the bottom of the bed by the blades. Thus there is a continuous turnover from top to bottom as the bed progresses down the sloping tank. The slurry is fed on to the top of the fluidised bed. In this device granulation can take place by layering and granulation—which is preferred—or by agglomeration and coating. The process lends itself readily to the production of a wide range of concentrated complex fertilisers.

The paper presented describes the present stage of development of the process, whose basic concepts were first applied in 1931 for the production of granular monoammonium phosphate at the plant of Consolidated Mining & Smelting Co. of Canada at Trail, British Columbia. The first plant operating the process in its present form to produce complex fertilisers and also diammonium phosphate was built at Joplin, Missouri, U.S.A., for the Missouri Farmers' Association (now Farmers' Chemical Co.) in 1955. A considerable amount of detailed data and a representative flowsheet have been published in the paper by permission of Dorr-Oliver.

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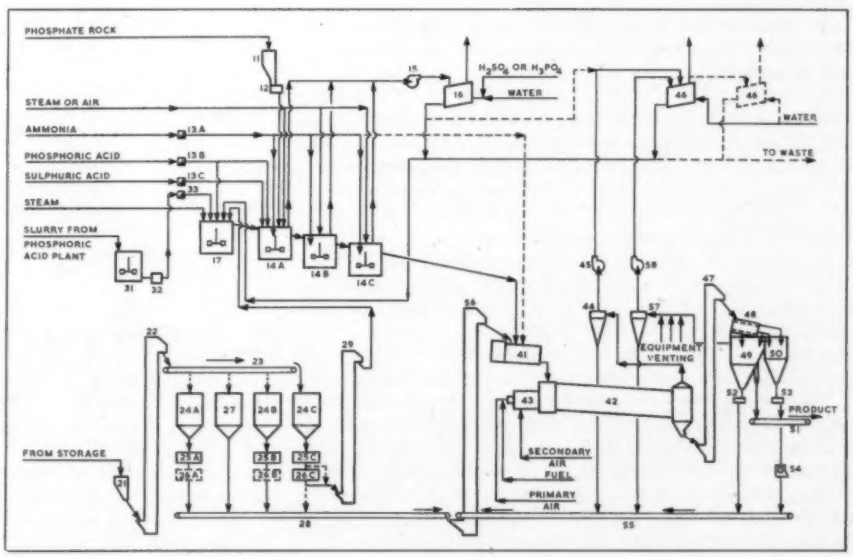

The Dorr-Oliver Granular Fertiliser Process Typical Flowsheet
11, phosphate rock bin; 12, gravimetric feeder; 13ABC, flow controllers; 14ABC, reaction agitators; 15, fume exhaust fan; 16, scrubber; 17, dissolving agitator; 21, feed hopper; 22, raw material elevator; 23, raw material conveyor No. 1; 24A, dry filler bin; 24B, potash bin; 24C, ammonium sulphate bin; 25ABC, raw material feeders; 26ABC, raw material mills; 27, salts bin; 28, raw material conveyor No. 2; 31, filler slurry storage; 32, filler pump; 33, filler flow controller; 41, blunger; 42, drier; 43, combustion chamber; 44, drier cyclone; 45, drier fan; 46, scrubber; 47, primary elevator; 48, vibrating screens; 49, fines bin; 50, oversize bin; 51, product conveyor; 52, fines feeder; 53, oversize feeder; 54, pulveriser; 55, fines conveyor; 56, secondary elevator; 57, dust cyclone; 58, dust fan.

TRENDS IN PROCESS CONTROL AND INSTRUMENTATION

IT is nowadays well recognised that the quality of control obtained from an automatic control system by matching the controller to the plant is limited not by the controller but by the dynamic characteristics of the plant itself. It is also widely appreciated that there is hazard in basing the control system upon constant process conditions, since an actual plant will be subject to a number of random disturbances which the control system, if it is to be successful, must be able to control.

The design of control equipment for chemical processes is still based in the main upon analyses of existing plants under operating conditions. Usually, the response characteristics are obtained by injecting into the plant through the valve controlling the relevant process condition, an oscillatory or step disturbance and by tracing the disturbance as it passes through the plant. In the case of the oscillatory injection, or frequency response method, the usual practice is to vary the input quantity to the system in a sinusoidal manner and to observe the corresponding sinusoidal variations in the output. By changing the period of the injected disturbance, the dynamic response of the plant can be obtained as a function of period.

The control engineer can estimate limits of control attainable from the control system, given frequency response data for each of the components comprising the plant, the form of the disturbances entering the plant, and their points of entry. A modification of this method eliminates the need for intricate mechanical devices for generating the pure sine-wave type of disturbance.[1] Thus an easily generated non-sinusoidal waveform can be used instead and the phase shift lags and attenuations obtained from a resolution of the injected and output waveforms into their fundamental and harmonic frequencies. The system is then designed to produce the proper response.

It is often difficult in practice to introduce the disturbances and often it is only permissible to use very small ones. This is an added incentive for developing other methods of determining the dynamic response characteristics of plants.

Predicting Dynamic Response

At its present stage of development the theory of automatic control does not yet furnish us with the means of predicting the response behaviour of plants with certainty, so that it is scarcely possible at present to consider the controllability of a plant at the design stage. This is a field where one has to deal with transient conditions.

However, most chemical engineering calculations assume steady-state operation, but most of the processes which the chemical engineer encounters are inherently unsteady-state in behaviour. With the drive for ever-greater use of automatic control there is an urgent need for the transformation of the chemical engineering concepts from the steady-state basis to the more realistic unsteady-state viewpoint in which the variations with time of the process variables are taken into account.

But even the investigation of a plant assumed to be operating under steady-state conditions, as KEETING and TOWNEND[2] have shown, can be an intricate undertaking. They investigated the relationship of such independent variables as feed rate, feed condition and composition, number and efficiency of plates, operating pressure, upon product composition and upon controllability of a superfractionator.

The recent contributions to the quantitative treatment of dynamic response show the effects of thermal and material capacity, and the resistance of the path by which the level is maintained, upon the time response to changes in the system. And already a comprehensive treatment of the dynamics of the simpler operations, such as mixing, has appeared in the form of the book "Process Dynamics".[3]

One method of arriving at the dynamic characteristics of processes and plants is by means of mathematical models. One such example refers to the stirred tank reactor in which an irreversible chemical reaction is taking place, the results of injecting random disturbances being obtained by means of a digital computer.[4] Another example applies to the characteristics of both batch and continuous stirred tanks, and it allows the behaviour of the continuous system to be predicted from results obtained from the equivalent batch mixer.[5]

From the transient point of view, the operation which has received the most attention has been distillation and much of the work in this field has dealt with calculation procedures for the prediction of the effect of external upsets upon operation within a column and with means of maintaining the purity of product. Although the role of hold-up has been recognised in this work little has been published until recently which offers a rational means of analysing the behaviour of hold-up in transient mass transfer operations. HUCKABA[6] derives a series of equations for stagewise and continuous contact equipment accounting for hold-up, and defines the conditions under which hold-up remains invariant. He also describes a number of methods for estimating the variation of hold-up with time.

Response from Electrical Analogue

The calculation of dynamic response is usually a complicated operation, but a method described recently by RIJNSDORP and MAARLEVELD[7] shows promise of eliminating the ardous nature of work of this kind. The method, based upon a theory of the dynamic response of distillation columns advanced by VOETTER[8], uses an electrical analogue to represent the distillation process. By linking the analogue to an analogue computer, the authors were able to simulate the behaviour of a 64-plate column distilling a

binary mixture. This method, which has the advantage of great speed, has been successfully applied to a small pilot-plant column as well as a full-scale refinery column.

In the future there seems little doubt that the control of reaction and separation processes will be based upon the measurement by analytical means of the process streams. As matters stand at present, except for binary mixtures, all the available methods require some finite period of time for the completion of the necessary analyses. The presence of such delay periods is clearly detrimental to control response and at the same time the reduction of the time required for analysis is a formidable task. Of considerable interest, therefore, is a recent paper[9] dealing with the loss of controllability arising from such delays. Here, again, analogue computer simulation techniques have been pressed into service.

Criterion of Controllability

It is necessary to have a suitable criterion for controllability. One criterion which has found some use is the deviation-reduction-factor—the ratio of the deviation without control to that with control. There is a snag in its application because in the comparison of two different control systems judgment may be required between the two different values of the criterion obtained for the two different operating periods of the systems. Another more satisfactory criterion appears to be the integral of the deviation squared, the minimum value of which has been shown by JACKSON[10] to offer a useful basis for the comparison of different control systems. A similar approach has been outlined by BATTEAU.[11]

Process Control Computers

A further important trend in process control proper is the extending use of computers. A simple form of computer, described by REDDING,[12] employs a force-balance transducer, and it can add, subtract and divide; when it is fed with analogue electrical signals representing process measurements, an output is obtained which corresponds to the solution of an equation. A number of applications are described in the relevant paper, for ratio control where the purpose is to maintain a quality such as *pH* in a mixture of two streams. Here the measuring device monitors this parameter in order to reset the ratio. The importance of this end-point control is that it not only renders the system self-correcting for variations in the input stream qualities, but it also ensures that it is self-correcting for errors in the flow measurements. Another important consequence of using such a device is that the number of measured variables can be increased and the number of controllers and regulating units can be reduced.

Greater use of computers for control purposes has been hindered through the absence of a process control computer designed specifically for this purpose, although there is little doubt that a number of important computer manufacturers are working to remedy this deficiency. In the U.S.A., for example, the RAMO-WOOLDRIDGE CORPORATION[13] are known to have at an advanced stage of development a digital control system consisting of a digital computer, and conversion equipment to provide analogue inputs and outputs. A particular feature of the design of the computer is its ability to accept in analogue form signals from a large number of measuring instruments, and to furnish in analogue form signals to a large number of control devices.

Another computer now available for application to an actual plant is the Ferranti Argus. This is a small transistorised unit which has successfully simulated the control of a plant for a period of more than a year. It is suitable for the direct control of the simpler processes.

Optimising Control of Processes

A particular field of computer control is where chemical reaction kinetics have to be considered. A process involving a chemical reaction as distinct from purely physical changes may, under certain operating conditions, give rise to loss of yield through the occurrence of side reactions. A number of variables may affect the process so that often the optimum conditions cannot be readily predicted from operating experience of the process. BOX[14] has developed a method for dealing with this type of situation with his so-called evolutionary operation technique. The procedure is to introduce small changes in a few of the variables into the process. These are designed to be made so small that the process is not seriously affected by them, but yet are large enough to show the direction in which changes should be made to improve the process. Once this has been ascertained, the series of variations is extended to find out the direction in which further improvement is likely to be found. The approach to the optimum conditions is obtained by analysing statistically the results of the variations in input variables. A computer could be used for this purpose and for causing the various controls to be gradually and continuously adjusted until the optimal point is reached. One advantage of this method is that it does not require a theoretical knowledge of the process behaviour, and already it has been applied in simplified form by the Dow Chemical Co. at their new styrene plant.

Another approach is that of LAPIDUS *et al.*[15] who use a computer for several purposes in cyclical order. In this method, the computer issues and sends a series of messages to the various controllers and it introduces also a series of changes into the process variables, examines the responses to these changes and issues the next series of changes. At the same time, it analyses the process measurements in order to establish an accurate model of the process dynamics from which, in turn, optimum control settings are derived. Yet another approach to process optimisation is via Uttley and Andrew's learning computer. In this method random changes are introduced into the settings of the controllers and the effects of these upsets are recorded in the memory of the machine and the control functions are made gradually to approach their optimum forms.

Before computers are more widely used, as well as an assurance of their complete reliability, an improvement will be needed in composition instruments and many new instruments of this kind will have to be developed. Otherwise the computer, an expensive item of equipment, is likely to be wasted because it must be fed with accurate information if it is to send the correct signals to the controllers.

Continuous Analysers

As mentioned earlier in this article, the growing emphasis on better control and the development of computer techniques for providing control functions is acting as a stimulus to process analysis instrumentation. An important point is that these instruments must be supplied with representative samples if their installation is to be successful. Of the techniques at present available, density and refractive index, although of considerable use in some situations, cannot be applied unambiguously to multi-component systems. The three principal instruments for analysis are the infra-red analyser, the gas chromatograph and the mass spectrometer and all have been considerably improved. The time lag in the sample system will seriously limit the response of any analyser, and for this reason it is doubtful whether an analytical system can be made fast enough for direct control; but, on the other hand, it is possible that it will be fast enough for set-point control.

Of these methods, the infra-red analyser is at the moment somewhat faster than the chromatograph; it can take liquid

samples and is better adapted to direct process control or applications where response time is critical. Nevertheless, gas chromatography is a particularly promising method especially for gas stream analyses, and if gas chromatography and the infra-red analyser can both do the analysis then the former is likely to be preferred. It is simpler and more easily maintained and can be readily adapted to handle changes in stream composition.

Recent designs of laboratory gas phase chromatograph will analyse very small samples, and the development of capillary columns greatly increases the component separation, providing at the same time a reduction in the time for analysis. Another development in the same field, showing how fast sample repetition times have become, is the display of the gas-chromatograph trace upon a cathode-ray tube.

The mass spectrometer, on the other hand, does not seem to be in a position to compete with either of these two instruments as a process stream analyser. It is much more expensive and its process applications are likely to be limited to situations calling for extreme rapidity of analysis. It is surprising, though, that the much simpler time-of-flight mass spectrometer[16] in which currents of different mass ions are selected according to their different velocities has not been further developed.

Other Instruments for Continuous Analysis

Photometry is another basis for analysis which is gaining wider acceptance. Instruments relying upon it are now available in this country from such manufacturers as Hilger & Watts and Southern Instruments. They can be used for continuous monitoring of solution concentration when this is related to colour, for determination of solids concentration in a liquid and, therefore, as a measure of the effectiveness of filtration processes.

For the continuous analysis of small concentrations of nitrogen in argon, BOROK and ALEXANDROV[17] have described an instrument in which a continuous sample is withdrawn from the main gas stream and subjected to a high-frequency discharge. The fluorescence thus produced is examined photoelectrically and the concentration indicated upon an electronic recording instrument. Concentrations of from 0 to 1% are detectable by this instrument, which is suitable for automatic control application. Among other gas analysers are two others with possible applications outside other than the purposes for which they were originally designed. The first of these, both designed by PAPPAS and WEBER of UNION CARBIDE[18] was intended for the continuous monitoring of uranium hexafluoride in gas mixtures; the second for the measurement and control of fluorine in process lines. The former instrument operates by detecting changes of molecular weight and viscosity of a fluid which passes through an orifice and a capillary in series. This may have applications to any gas or liquid stream where density or viscosity varies with concentration of the component being measured. The underlying principle of this instrument is that pressure response at the capillary varies with molecular weight and at the orifice it varies with viscosity. In practice, the pressure upstream of one restriction is maintained constant, whereas the change in pressure at the other restriction serves as a measure of concentration. Corrosion-resisting materials can be used in the construction of this instrument. The other instrument is a continuous titration analyser based upon the changes in molar volume and hence pressure which occurs when two gases react. In the production model, however, the reaction is carried out continuously and changes in flow rather than changes in volume produce the pressure response which, in turn, indicates the concentration of the reactant being analysed in the process stream.

Another analytical instrument determines the SO_3 or sulphuric acid in gases in the range 5-100 ppm. It operates by absorbing the trioxide or acid in isopropyl alcohol solution and by precipitating it as barium sulphate. The sequences of operation are carried out within eight minutes, the turbidity of the solution being measured photoelectrically.

Control of Fluid Bed Reactors

Typical of the newer electronic techniques entering the field of process control is a recent invention for the control of the quality of fluidisation in fluidised-bed reactors. The instrument consists of an electrically-heated probe which is inserted in the fluid bed. The quality of fluidisation is deduced from the heat-transfer coefficient which, in turn, is measured by the amount of energy required to maintain the probe at a constant temperature. The probe consists of an insulated thermistor made from metallic oxides and it is constructed so that it is exposed to direct contact with the fluidised solids, a feature which reduces the response time of the probe to transients. The thermistor has high electrical resistivity coupled with high negative temperature coefficient of resistance and very low thermal capacity. An electronic circuit is provided for the purpose of maintaining the probe at constant temperature and for measuring the power input from which the heat-transfer coefficient from probe to bed and hence the quality of fluidisation can be deduced. The underlying assumption with this instrument is that the heat-transfer coefficient so obtained is a fair measure of the quality of fluidisation around the probe. Unlike the capacitive method, this one is unlikely to cause non-uniformity of fluidisation in its vicinity, for the thermistor itself is no more than 0.04 in. in diameter.[19]

Improved Measuring Instruments

Many improvements have been made in the primary measuring instruments for such variables as flow pressure, temperature and level. It is now possible, for instance, for the levels in tanks to be remotely gauged with a precision of 1/20th in. in a height of over 25 ft. This kind of accuracy is extremely useful because it leads to greater utilisation of tank capacity compared with that possible when the accuracy is the 1/10th in. obtained with local dipping. It is, however, essential to know, when using the more precise methods, the average temperature of the tank contents, since changes in this variable can lead to changes in level within the precision of measurement.

Advances in Flow Measurement

A number of developments in the field of flow measurement revealed at a recent symposium[20] included the electromagnetic flowmeter. This instrument gives a linear indication of the volume rate of flow, provided the liquid passing through it has a conductivity above a certain minimum value. It is suitable for slurries and will respond to flow pulsations. Also described were a mass flowmeter with the disadvantage of a rotary element, a propeller flowmeter in which the main improvement was in the manner of measuring the speed of rotation, and a meter based upon the change in the apparent velocity of sound produced by the liquid flow. The field of this latter instrument appears to be limited to very high velocity measurements.

Among other developments in the sphere of flow measurement is the ultrasonic flowmeter developed by the B.S.I.R.A. This is another non-restrictive type incurring no head loss, and it has been designed primarily for the measurement and control of awkward fluids and slurries flowing at the comparatively slow rates encountered in the process industries. Like the sonic meter mentioned above,

this one too can respond to pulsating flows. Another flow-measuring device worthy of mention is the Bopp & Reuther double venturi, the development of which has been paralleled by that of the Dall tube in this country. The motivation behind these devices was the need to have a measuring means with a stable coefficient over a wide range of Reynolds number, with head loss characteristics lower than those produced by venturis, possessing a low laying length and being comparatively inexpensive to manufacture. Of the two devices, the double-throat venturi has the shorter laying length; its other characteristics have been described in detail by KALINSKE.[21] However, Geo. Kent, the manufacturers of the Dall tube, have introduced a modification of the Dall tube with a much shorter laying length than its parent, but which incurs a somewhat higher pressure loss.

While on the subject of flow measurement, mention should be made of attempts to extend the use of variable-area flowmeters to higher temperatures and pressures and to fluids different from those normally metered by them. One promising method which has been tested with this aim in view makes use of a float-type meter, but obtains the indication of flow rate through measurement of the absorption of gamma-radiation by the float.[22]

Viscosity Correction

A further useful contribution to the techniques of fluid flow measurement is an analysis of the effect of viscosity upon the accuracy of axial-flow turbine-type flowmeters, followed by a description of a method by which an instrument of this type can be compensated for viscosity.[23] The method consists of fitting to the rotor of the meter an additional element which imposes an additional torque, related to the viscosity of the liquid being metered, resisting rotation of the rotor.

Temperature Measurements

In the field of temperature measurement there is a possibility that use could be made of the different electrical behaviour of graphites prepared by cracking hydrocarbons on to strip carbon at elevated temperature when the structure of the carbon becomes orientated. By means of a thermocouple of orientated and ordinary graphite, temperatures as high as 2400°C should be measurable with reliability. The introduction of the tungsten *v.* tungsten-rhenium thermocouple has extended the ranges of temperature which can be measured by this means to 2800°C, although in this particular instance an oxidising atmosphere must not be in contact with the thermocouple proper. Thermistors also are gradually entering the field of thermometry.

New Density Measuring Methods

For the continuous monitoring of density some ingenious nucleonic instruments have been introduced based upon the measurement of the absorption by the process fluid of radiation from an isotopic source. Two Russian developments for continuous density measurements are also worthy of note. The first is a vibrator type[24] and it is based upon the principle that the density of fluid, contained in a section of pipeline connected to the main process line by means of flexible connections, is related to the amplitude of vibration of the fitting. The second makes use of a float filled with a liquid of density similar to that being measured, with the lower end of the float formed by a bellows. Thus when the density of the liquid around the float changes, so does the volume of the float. This change is converted by means of an electronic circuit into a density reading. Accuracy is stated to be 0.001 gm/cc for liquids within the range of densities 0.750 to 0.800 gm/cc.[25]

Electrical Control Systems

Most control systems in the process industries are pneumatically operated and pneumatic controllers embodying the various control actions, such as derivative and inverse derivative, have reached a high pitch of dependability. The electric systems are now offering a strong challenge to pneumatic systems. The past few years' history of the electric systems looks something like a derivative control action in response to a step upset; it jumped to a peak, fell back and is now climbing back again. Possibly the trend in the future will be for a proportionately greater employment of the electrical systems, since they have many advantages and reliability is much improved. Although non-interacting pneumatic controllers are in existence, notably Negretti & Zambra's controller, this is not a feature common to them, and the electrical systems will provide the basic control actions without interaction. This is a great advantage because it means, for example, that pure derivative action becomes possible and with it the advantage of greater phase advance. A more highly damped response with reduced overshoot compared with that obtainable from pneumatic systems is also achieved. Of value also, particularly with some flow control applications, is the reduction in transmission lags which the electrical systems provide. There are, of course, objections to the use of electrical methods, such as what will happen when there is a power failure and how to render them safe in the presence of inflammable and explosive gases. But these problems are surmountable and are not a fundamental objection to the wider use of electrically-operated control equipment.

There is, however, the need to develop a final control element with greater speed of response than many of the currently used electro-pneumatic valves, or than provided by electrically-operated valve actuators, except where simple on-off control is adequate when a magnetic valve can be used. One answer to this problem is the thermo-drive actuator introduced by the Swartwout Co. of the U.S.A. In this valve motor the pressure on the diaphragm is provided by the evaporation of a liquid, the pressure itself being controlled by a reflux condenser. Input of coolant to the condenser is controlled by an electrically-operated valve to which the output signal of the controller is fed.[26]

The advantages of electrical control are realised fully when combined with a computer device of the type described by REDDING, and already this combination has been very successfully employed for the control of sugar refining processes. In this case the final control elements may be electrically-actuated, electro-hydraulic and electro-pneumatic valves and variable-speed controls for pump motors.

Data Logging

The formidable array of instruments to be found in the control room of many modern plants, arising from the large number of process variables being measured, recorded and controlled, presents a number of problems. There is the difficulty of accommodating the mass of instruments required, which can be partly overcome by the use of miniature instruments. Where the instruments are mounted upon a graphic or semi-graphic panel, if a large number of variables are indicated the whole set-up may be extremely confusing to the operator. Indeed, the limits of expanse for instrument panels and control rooms are being reached.

The concentration of instruments into a monitoring desk with in-line scanners to draw attention to deviations from critical process conditions is a partial solution to this problem, but the data logger is a more complete answer. This device will accept measurements converted into electrical signals by suitable transducers, scan each signal in turn and print out a record of the measurements, in black if they fall within the required limits or in red if they fall outside them.

(To be continued)

GUIDE TO PROCESS INSTRUMENTATION — PART 1

MEASURED OR CONTROLLED VARIABLE: TEMPERATURE

Type of measuring instrument	*Application*	*Range of instrument or control system may fall within the stated limits*	*Accuracy as percentage of full scale range*	*Suitability for remote indication and automatic control*	*Remarks*	*Maker or supplier*
Expansion of organic liquid in metallic system	Used for low-temperature gas, liquid and solid process streams and for short range intervals	−200°C to 320°C	±0.5 to ±1	Remote indication possible. Capillary lengths of 200 ft are customary. With pneumatic transmitters can be part of automatic control system	Above 25-ft length of capillary, double capillary required	B 6. C 1. D 6. E 10. F 10. G 2. K 1. N 3. T 1.
Expansion of mercury or mercury-thallium in metallic system	For process streams, especially where accuracy over a wide span is desired	−55°C to 630°C	±0.25 to ±1	Suitable remote indication, electro-pneumatic, and electric automatic control. Some makes available with 450 ft of capillary; electrical contacts for on-off control	Has uniform scale graduations over entire range. Has great power	A 11. C 1, 2. F 10. G 2. K 3. N 3. T 1.
Expansion of mercury or organic liquid in glass	Used for taking local readings in pipelines and tanks	−200 °C to 630°C	±0.5 to ±1	Not suitable for either remote indication or automatic control	Fragile, but can be supplied with protective sheathing. Types available for surface measurement.	B 12. C 2. N 3, 4. T 1. W 5. Z 1.
Pressure change, vapour pressure type	Measurement or control where operating range is within restricted limits	2°K to 350°C	±0.5 to ±1	Suitable remote indication recording and automatic control	Rapid response. Has a non-uniform scale with degree spacing increasing with temperature	B 6, 9. C 1, 4. D 6. E 10, 16. F 10. G 2. N 4. S 11. T 2, 4.
Pressure change, gas-filled types	Process fluids where temperature changes around measuring element are small	4°K to 540°C	±0.5	Suitable remote indication recording and automatic control	Have uniform graduations over entire scale. Fast response but require large bulb	B 1, 6. C 1. E 1, 4, 16. F 10. G 2. S 9. T 1.
Bimetallic	Local indication of temperature for gases, solids and liquids	−160°C to +700°C	±0.5 to ±1	Local reading. Electrical contacts can provide on-off control	Requires recalibration if roughly handled. Stem section must be completely immersed for accuracy	B 7, 9. C 2. G 2. M 1. S 11. T 2. Z 1.
Thermocouple	Measurement of temperatures at many points of process fluid	1°K to 2800°C. Gold-cobalt *v.* gold-silver for very low temperatures. Tungsten-rhenium *v.* tungsten for higher end of range	±0.25 to ±0.5	Suitable remote reading, recording and automatic control by electric or pneumatic systems	Higher temperatures can be measured for short exposures (spot readings)	C 1. D 1. E 2, 8, 10, 14, 16. F 3, 9, 10. G 2. H 5. I 1, 3. K 2, 3, L 1, 2. P. 7. S 7, 9. W 2, 3.
Resistance. Measures resistance of element and balances this on a bridge circuit	Suitable solids and fluids. Multipoint measurement. Bulbs available for surface measurement. Suitable for narrow ranges	4°K to 900°C. Indium resistance elements have been used at the lower limit of this range	±0.1 to ±0.4	Suitable remote reading, recording and automatic control by electric or pneumatic systems	Higher accuracy than thermocouple. One type of Pt resistance thermometer has an accuracy of 0.025% of full scale range	A 7. B 7, 9. C 1, 5. E 8, 10, 12, 14, 16. F 3, 9, 10. G 2. H 5. I 3. K 2, 3. L 1, 2. S 1, 2, 7, 9. T 2, 4. W 2, 3, 6.
Suction (thermocouple) pyrometer	Accurate measurement of temperature of hot gases; e.g., in water tube boilers	Upper limit 1600°C	±1 to ±3	Remote reading and recording possible. Not used for automatic control	Ensure linear velocity of gas according to maker's instructions	F 9, I 1, L 2.

Measured or Controlled Variable: Temperature, cont.

Type of measuring instrument	*Application*	*Range of instrument or control system may fall within the stated limits*	*Accuracy as percentage of full scale range*	*Suitability for remote indication and automatic control*	*Remarks*	*Maker or supplier*
Thermistor type. In conjunction with bridge circuits	For measuring temperatures accurately within extremely narrow ranges; e.g., 1°C	−190°C to +400°C	±0.1 over narrow ranges	Suitable remote indication, recording automatic control	May suffer from drift at upper end of range	H 2. K 4. R 1. T 3.
Radiation pyrometer	For measurements where the atmosphere is damaging to thermocouples; e.g., rotary kilns, hot strip mills	150°C to 2200°C	±0.5 to ±2 depending upon type	Some types provide remote indication recording and on-off control	Smoke, fume, dust. CO_2, H_2O and SO_2 affect accuracy if field in view. Correction needed when sighted on non-black bodies	C 1, E 10, 14, 16. F 9. G 2. H 5. I 3. K 3. L 1. R 1.
Optical pyrometer	Measuring high temperatures of remote and inaccessible objects such as molten metals and furnace interiors	700°C to 2900°C	±1.5	Cannot operate a recorder or lend itself to automatic control	Accuracy suffers if fumes and flames present	C 1. E 10, 14, 16. F 9. G 2. I 3.

MEASURED OR CONTROLLED VARIABLE: RATE OF FLOW

Type of measuring instrument	*Application*	*Maximum flow rates fall within the stated limits*	*Accuracy as a percentage of full scale reading*	*Suitability for remote indication and automatic control*	*Remarks*	*Maker or supplier*
Variable Area Meters Size of restriction adjusted according to constant pressure. Tapered rotameter, glass tube type	Clean process fluids at small and moderate flow rates	0.025 to 3000 gph of water. 0.2 to 5500 cfh of air. Guided types permit greater throughputs	±2	Local reading only. Automatic control not possible with this type	These instruments have a greater range than differential meters. Range usually 10–100% of max. flow. Pressures of 34 atm. for small glass instruments, 7–8 for larger models	E 4. F 6. R 4. P 5.
Metal tapered tube with sight glass and scale	For gases and liquids at higher rates of flow than glass-tube types allow	40–1500 gpm based on water. For gases, permissible pressure drop determines maximum throughput	±2		Tolerate much higher pressures and temperatures than glass-tube types. Flow measurement of opaque fluids if sight glass is pressurised to exclude fluid. Pressures up to 500 psi	E 4. F 6. R 4.
Magnetic rotameter. Pneumatic transmitting	Clear and opaque liquids, slurries at low and high temperatures and at higher pressures than other rotameter types	250–2500 gph (water)	±2	Remote indication, recording and automatic control possible with electric and pneumatic transmitter types	Suitable for temperatures in the range −180 to 350°C. Pressures up to 5000 psi	E 4. F 6. R 4.
Magnetic rotameter. Electric transmitting		40–1500 gpm (water)	±2			
Piston types, weight or spring loaded	Flow measurement of hot tar, black liquor and viscous liquids generally	0 to 2000 gph. Greater outputs can be obtained by operating in parallel	±1	Can be arranged for recording and automatic control	Viscosity exerts less influence than with rotameter. Liquids only. Pressure losses range from ½–10 psi	B 1. H 5.

Measured or Controlled Variable: Rate of Flow, cont.

Type of measuring instrument	*Application*	*Maximum flow rates fall within the stated limits*	*Accuracy as a percentage of full scale range*	*Suitability for remote indication and automatic control*	*Remarks*	*Maker or supplier*
Positive Displacement Meters. Oscillating piston	Accounting water. Batching solvents, viscous liquids such as heavy fuel oil, bitumen, condensed milk, etc. Metering corrosive fluids	8 to 40,000 gph. (Higher rates possible for short periods)	±0.1 to ±1	Remote reading recording and fully automatic control possible with some types	Gritty fluids can also be handled by some makes	G 1. K 3. L 5. M 4.
Lobed rotor	Metering large gas flows	Up to 10^6 cu.ft/hr	±1 to ±2	Not usually associated with automatic control. Remote indication possible	Has low pressure loss and little slip	H 8.
Differential-pressure Meters Types based upon flow restriction such as an orifice and the measurement of differential pressure by a mercury manometer	Metering process fluids that are not too viscous nor with high percentages of solids	Flow rates corresponding to differentials up to 500 in. water. Orifices for pipe sizes up to 48 in	±1 to ±2	Readily form part of automatic control system, either pneumatic or electric	High pressure loss. Require cleaning for maintenance of accuracy. Not accurate below 25% of max. flow	B 1, 6. E 4, 10, 16. F 6, 10. H 5, 7. K 2, 3, 4. S 11. T 1.
Mercuryless manometer for differential pressure measurement	Metering highly inflammable process streams	Differentials up to 600 in. Water pipe sizes as above	±2	do.	Absence of mercury eliminates hazard of blowing into the line. Satisfactory for high working pressures	B 1, 6. E 10, 16. K 3. F 6, 10. G 2. H 5. S 11. T 1.
Force-balance type of differential balance pressure measurement	Where differential pressures are small and high accuracy important	Differentials up to 900 in. water	±2	do.	Has a faster response than mercury-containing meters	B 6. C 3. E 4, 10, 16. F 10. K 3. S 11, 12. T 1.
Restriction to flow by venturi	Large flows of gases and process liquids. Satisfactory where large proportion of suspended solids and where high accuracy desired	Up to 48-in. pipe bore	±0.5 to ±1	do.	Less head loss than with orifices	B 1, 6, 8. E 4, 10, 16. F 6, 10. H 5. K 3. S 11. T 1.
Restriction to flow by special flow-tube; e.g., the Dall or Gentile	Used for metering fluids containing solids in high proportions	Restricted only by pipeline size	±0.5 to ±1	do.	Induces a higher differential pressure than a venturi. Permanent pressure loss 5% of total	K 3.
Pitot	Secondary standard for checking flow-meter installations. In large pipe sizes occasionally used for giving an indication of total flow	do.	±1 to ±2	Not normally associated with an automatic control system	Small openings clog if solid particles present. Pressure differential small	B 1, 6, 8. E 4, 10, 16. F 6, 10. K 3. N 3. S 11. T 1.
Pitot-Venturi	Measuring local or total flow rates of process streams unlikely to deposit solids	No limitation other than differential. Can be constructed to fit into any size of pipe	±0.5 to ±1	As with other differential meters in conjunction with transmitters and controllers can form part of an automatic control system	Differential 7–10 times greater than with pitot. No pressure loss. When placed in the average velocity position in a duct, can be used as a flow-meter	T 1.

Measured or Controlled Variable: Rate of Flow, cont.

Type of measuring instrument	*Application*	*Maximum flow rates fall within the stated limits*	*Accuracy as a percentage of full scale range*	*Suitability for remote indication and automatic control*	*Remarks*	*Maker or supplier*
Bell meter used for differential pressure measurement	For very low flow rates of gases and liquids	Differentials up to 5 in. water	±1 to ±2	As with other differential meters in conjunction with transmitters and controllers can form part of an automatic control system	—	B 6, E 4. H 5. T 1.
Magnetic	For volume rate of flow of corrosive fluids, sludges, pulps	Max. throughput limited by pipe diameter.	±1	Remote indication and recording	Material of tube lining required by these instruments limits temperature of application. Suitable for high pressures	A 6. E 4. K 3. M 4.
Shunt	Used for process steam distribution systems, compressed air. Suitable for fluctuating flows, discharge from reciprocating pumps	Up go 3000 scfm of air at 100 psig	±2	Local reading. Can be combined with remote indicator	Not usually employed for temperatures above 260°C or at pressures above 250 psig	K 3.
Rotary electronic	Metering corrosive and dangerous fluids and gases under pressure, e.g., liquid oxygen	0.1 gpm to 1800 gpm	±1	Can be used for remote recording and automatic control	Response to changes in flow rate very rapid. Can be used for high pressures, e.g., up to 400 psi	E 8. I 6.

MEASURED OR CONTROLLED VARIABLE: LIQUID LEVEL

Type of instrument for measuring variable	*Application*	*Instrument has range falling within the given limits*	*Accuracy of measurement in in. or as a percentage of full scale range*	*Stability of instrument for remote indicator and/or automatic control*	*Remarks*	*Maker or supplier*
Chain or tape float gauge	Contents of open vessels, small level changes measured accurately	0 to 50 ft	±½ in. of liquid level	Transmitters, pneumatic or electrical, can be incorporated for automatic control and remote indication	Mechanism must be maintained clean for reliable operation	B 6. E 10. K 3. P 1.
Buoyant float types	Liquids in tanks under moderate pressures or under vacuum	Up to 10 ft	±2	Local or remote reading	Float can be supplied in various materials for corrosive liquids	F 7. K 3. H 7. R 4. S 9, 11.
Magnetic bond type	Suitable closed vessels containing opaque liquids	0 to 15 ft	±1	Can operate limit switches. Remote indication not usual	Suitable for measurement of dangerous fluids stored under pressure	F 8. L 9. R 4.
Chain level	Gas holder height, continuous record	0 to 50 ft	±1	Remote indication and recording possible	—	E 10. P 1.
Static pressure method. Pressure gauge calibrated in terms of liquid level	Depth of liquid in open vessels. Including highly viscous liquids, level of liquids in any open or vented tanks	0 to 35 ft water (bellows) 0 to 70 ft water (diaphragm)	±1	Control, recording possible with some makes	Satisfactory, provided no serious change in sp. gr.	B 1. A 7. K 1. N 3. P 3. S 11. T 1.
Hydrostatic pressure on capsule or bulb		0 to 50 ft water	±1	Control, recording possible with some makes	A range of bulbs can be supplied according to conditions: e.g., whether corrosives or abrasives are present	B 1, 6. F 5, 7. K 3. P 3. S 11. T 1.

Measured or Controlled Variable: Liquid Level, cont.

Type of instrument for measuring variable	*Application*	*Instrument has range falling within the given limits*	*Accuracy of measurement in in. or as a percentage of full scale range*	*Suitability of instrument for remote indicator and/or automatic control*	*Remarks*	*Maker or supplier*
Pneumatic reaction	Storage of chemicals. Suitable for closed vessels at pressures up to 100 psi	0 to 300 ft water	±1 to ±3	Control, recording possible with some makes	Not recommended for highly toxic materials. Suitable for suspensions	B 6. D 4. K 1, 3. F 5, 10. H 7, 9.
Differential pressure method based upon force balance transmitter	Measurement of levels of viscous or corrosive liquids and slurries	0 to 800 in. H_2O	±1	Remote recording and automatic control possible	Pressures up to 1500 psi and temperatures up to 350°F (process fluid) can be tolerated	B 6. E 10. F 10. K 3. T 1. S 11, 12.
Differential pressure aneroid	For all liquids in open or closed vessels under pressure or vacuum especially where levels fluctuate	0 to 500 in. H_2O	±1	Remote recording and automatic control possible	Mercury losses avoided. Maximum working pressures vary from 100 to 2000 psig	T 1.
Differential pressure mercury U-tube	Measuring level in vessels under pressure or vacuum	0 to 400 in. H_2O	±1	Remote recording and automatic control possible	Bell-type manometer can be used for very small level changes	B 6. E 4. F 10. K 3. H 9. T 1.
Mercury counterpoise type	Recording level in elevated tanks, tanks, where instrument is to be mounted at ground level	0 to 400 in. H_2O	±1	Remote recording and automatic control possible	Has been used for tanks with an upper level approaching 100 ft above ground	B 6.
Displacer-type torque tube	Measurement of levels of many chemicals: e.g., butadiene, styrene, etc., inc. interface levels	Displacer lengths up to 20 ft. Liquids of sp. gr. 0.2 to 2 can be handled	±1	Remote recording and automatic control possible	More responsive to level fluctuations than buoyant float types	E 4. F 7. T 1.
Displacer type—force balance	Suitable for liquid—liquid interfaces where specific gravities are close together	Displacer lengths up to 20 ft	±1	Remote indication recording and automatic control usual	Displacers can be supplied in special materials for corrosive fluids	E 4. K 3. T 1.
Displacer type—buoyancy measured electronically	Measurement of liquid level or interface of two immiscible liquids in closed vessels	Displacer lengths up to 20 ft	±1	Remote and local indication combined with electrical or electro-pneumatic or hydraulic control	Suitable for pressures up to 600 psi	E 16.
Electronic displacer type plus probe	Measurement and indication of level or interface level of liquids. Suitable hydrocarbons and acids	0 to 60 ft	$\frac{1}{16}$ in. for level and interface level	Remote and local indication	Transmission possible over great distances	E 16.
Gamma-ray absorption type	Level measurement and control of high-pressure, high-temperature fluids. Suitable interface detection	3 in. to 5 ft	±3	Remote indication recording and control possible either of the on-off or three-term mode	Suitable for use at elevated temperatures and/or where abrasive solids are present	E 2. L 5. L 10, 11.

Measured or Controlled Variable: Liquid Level, cont.

Type of instrument for measuring variable	*Application*	*Instrument has range falling within the given limits*	*Accuracy of measurement in in. or as a percentage of full scale range*	*Suitability of instrument for remote indicator and/or automatic control*	*Remarks*	*Maker or supplier*
Capacitance types. Capacitance changes with liquid level change	Levels of liquids in closed vesesls	No limit other than vessel dimensions	±1	Electrical or electrical-pneumatic control possible	High corrosion resistance readily imparted. Good where conditions against other types. Scum or foam on airface of liquid may introduce error. Temperature may upset measurement	E 3, 16. F 3, 5. H 1. L 1, 9, 10. R 1. T 5. W 4.
Electrical conductivity. Electrode system	Control of level in storage tanks, pump control. High or low level alarms	Level range limited solely by vessel dimensions	±2 to ±3	In conjunction with electrical relays, provides automatic control	Pressures as high as 3000 psi permissible. Electronic types suitable for liquids with resistivities up to 20 megohm-cm. Electrical types for resistivities up to 20,000 ohm-cm.	E 10. F 7. K 3.

List of Instrument and Automatic Process Control Equipment Makers

A
1. Adequate Weighers Ltd., Sutton, Surrey.
2. A.E.I. Instruments Division, Trafford Park, Manchester, and Rugby.
3. Airflow Developments Ltd., High Wycombe, Bucks.
4. Airmec Ltd., High Wycombe, Bucks.
5. Alexander Controls Ltd., Sutton Coldfield, Warwicks.
6. Alto Instruments Ltd., London, W.C.2.
7. Andec Ltd., Reading, Berks.
8. Appleby & Ireland Ltd., Basingstoke, Hants.
9. W.T. Avery & Co. Ltd., Birmingham.
10. Avery Hardoll Ltd., Chessington, Surrey.
11. A.W.I. Instruments Ltd., Woking, Surrey.

B
1. Bailey Meters & Controls Ltd., Croydon, Surrey.
2. Barnet Instruments Ltd., Barnet, Herts.
3. Bayham Ltd., London, W.1.
4. Bellingham & Stanley Ltd., London, N.19.
5. B & K Laboratories Ltd., London, W.1.
6. Bristol's Instrument Co. Ltd., London, S.E.13.
7. British Arca Regulators Ltd., Gloucester.
8. British Pitometer Ltd., London, N.W.10.
9. British Rototherm Co. Ltd., London, S.W.19.
10. British Thomson-Houston Co. Ltd., Rugby.
11. Bryans Aeroquipment Ltd., Mitcham, Surrey.
12. Budenberg Gauge Co. Ltd., Broadheath, Lincs.

C
1. Cambridge Instrument Co. Ltd., London, S.W.1.
2. C. F. Casella & Co. Ltd., London, W.1.
3. Cheltenham Auto Controls Ltd., Cheltenham, Glos.
4. Coley Thermometers Ltd., Brentford, Middx.
5. Craven Electronics Ltd., Bradford, Yorks.
6. Crosby Valve & Engineering Co. Ltd., Wembley, Middx.

D
1. Danfoss Manufacturing Co. Ltd., London, W.2.
2. Davey & United Instruments Ltd., Sheffield.
3. Dewrance Ltd., London, S.E.1.
4. Dobbie McInnes Ltd., Glasgow.
5. Doran Instrument Co. Ltd., Stroud, Glos.
6. Drayton Regulator & Instrument Co. Ltd., West Drayton, Middx.
7. Dunford & Elliott Ltd., Sheffield.

E
1. Edwards High Vacuum Ltd., Crawley, Surrey.
2. Ekco Electronics Ltd., Southend, Essex.
3. Elcontrol Ltd., Hitchin, Herts.
4. Electroflo Meters Ltd., London, N.W.10.
5. Electromechanical Systems Ltd., Feltham, Middx.
6. Electromethods Ltd., Stevenage, Herts.
7. Electronic Instruments Ltd., Richmond, Surrey.
8. Electrothermal Engineering Ltd., London, N.E.7.
9. Electroweighers Ltd., Birmingham.
10. Elliott Brothers Ltd., London, S.E.13.
11. Engelhardt Industries Ltd., London, W.C.1.
12. English Electric Co. Ltd., London, W.C.1.
13. Ericsson Telephones Ltd., New Basford, Notts.
14. Ether Ltd., Birmingham.
15. Evans Electroselenium Ltd., Halstead, Essex.
16. Eversbed & Vignoles Ltd., London, W.4.

F
1. Fairey Aviation Ltd., Hayes, Middx.
2. Ferranti Ltd., Hollinwood, Lancs.
3. Fielden Electronics Ltd., Wythenshawe, Lancs.
4. Fireye Controls Ltd., London, E.C.4.
5. Firth Cleveland Instruments Ltd., Pontypridd, Glam.
6. Fischer & Porter Ltd., Workington, Cumberland.
7. Fisher Governor Ltd., Rochester, Kent.
8. Flight Refuelling Ltd., Blandford, Dorset.
9. Foster Instrument Co. Ltd., Letchworth, Herts.
10. Foxboro-Yoxall Ltd., Redhill, Surrey.

G
1. Gilbarco Ltd., London, N.17.
2. James Gordon & Co. Ltd., Stanmore, Middx.
3. Grundy & Partners Ltd., Teddington, Middx.

H
1. J. Edward Hall Electrical Engineers Ltd., Dartford, Kent.
2. Headland Engineering Developments Ltd., London, S.E.15.
3. Hilger & Watts Ltd., London, N.W.2.
4. H.J.S. Industrial Instruments Ltd., Birmingham, 5.
5. Honeywell Controls Ltd., Greenford, Middx.
6. Howard Clayton-Wright Ltd., Wellesbourne, Warwicks.
7. Hunt & Mitton Ltd., Birmingham, 1.
8. W. C. Holmes & Co. Ltd., Huddersfield, Yorks.
9. H. M. Hobson Ltd., Wolverhampton.

I
1. Industrial Pyrometer Co. Ltd., Birmingham, 5.
2. Infra-Red Developments Ltd., Welwyn Garden City, Herts.
3. Integra, Leeds & Northup Ltd., Birmingham.
4. International Combustion Co. Ltd., Derby.
5. Isotope Developments Ltd., Reading, Berks.
6. Integral Ltd., Wolverhampton.

K
1. K.D.G. Ltd., Crawley, Surrey.
2. Kelvin & Hughes Ltd., Wembley, Middx.
3. George Kent Ltd., Luton, Beds.
4. Wayne Kerr Laboratories Ltd., Chessington, Surrey.

L
1. Lancashire Dynamo Electronic Products Ltd., Rugeley, Staffs.
2. Land Pyrometers Ltd., Sheffield.
3. Langham Thompson Ltd., Bushey Heath, Herts.
4. Lea Recorder Co. Ltd., Manchester, 15.
5. Leeds Meter Co. Ltd., Leeds, 12.
6. Lindars Automation Ltd., Surbiton, Surrey.
7. Lintronic Ltd., London, W.C.2.
8. Liquid Systems Ltd., Redhill, Surrey.
9. Londex Ltd., London, S.E.20.
10. A.M. Lock & Co. Ltd., Oldham, Lancs.
11. Labgear Ltd., Cambridge.

M
1. Robert MacLaren & Co. Ltd., Glasgow, C.5.
2. Manchester Water Meter Co. Ltd., Manchester, 12.
3. Marconi Instruments Ltd., St. Albans, Herts.
4. Measurement Ltd., Oldham, Lancs.
5. Megatron Ltd., London, N.4.
6. Mervyn Instruments Ltd., Woking, Surrey.
7. Metropolitan-Vickers Ltd., Trafford Park, Manchester.
8. Mine Safety Appliances Ltd., Glasgow, E.3.

N
1. Nalder & Thompson Ltd., London, E.8.
2. Nash & Thompson Ltd., Chessington, Surrey.
3. Negretti & Zambra Ltd., London, W.1.
4. Nottingham Thermometer Co. Ltd., Birmingham, 5.

P
1. Parkinson Cowan Instruments, London, S.E.11.
2. Sir Howard Grubb Parsons, Newcastle upon Tyne, 6.
3. Payne & Griffiths Ltd., Smethwick, Staffs.
4. Philips Electrical Ltd., London, W.C.2.
5. G. A. Platon Ltd., Croydon, Surrey.
6. Pulsometer Engineering Co. Ltd., Reading, Berks.
7. W. G. Pye & Co. Ltd., Cambridge.

R
1. Radiovisor Parent Co. Ltd., London, S.W.19.
2. Rheostatic Co. Ltd., Slough, Bucks.
3. Richardson Scale Co. Ltd., Nottingham.
4. Rotameter Manufacturing Co. Ltd., Croydon, Surrey.

S
1. Sangamo Weston Ltd., Enfield, Middx.
2. Sargrove Electronics Ltd., Hounslow, Middx.
3. S.E. Laboratories Ltd., Feltham, Middx.
4. Servis Recorders Ltd., Gloucester.
5. Servomex Controls Ltd., Crowborough, Sussex.
6. Shaw Moisture Meters Ltd., Bradford, Yorks.
7. Sifam Electrical Instrument Co. Ltd., Torquay, Devon.
8. Simmonds Aeroaccessories Ltd., Pontypridd, Glam.
9. Smiths Industrial Instruments Ltd., London, N.W.2.
10. Solartron Electronic Group Ltd., Kingston, Surrey.
11. Sunvic Controls Ltd., London, W.C.2.
12. Swartwout Co. Ltd., London, S.E.13.
13. Salford Instruments Ltd., Salford, Lancs.
14. Sigma Instrument Co. Ltd., Letchworth, Herts.

T
1. Taylor Controls Ltd., London, E.17.
2. Teddington Industrial Equipment Ltd., Sunbury-on-Thames, Middx.
3. Texas Instruments Ltd., Bedford.
4. Thermocontrol Installations Co. Ltd., London, S.E.1.
5. Thomas Industrial Automation Ltd., Altrincham, Ches.
6. Ronald Trist Ltd., Slough, Bucks.
7. Tylers of London Ltd., Burgess Hill, Sussex.
8. John Thompson Instrument Co. Ltd., Wolverhampton.
9. Tomey Industries Ltd., Birmingham, 6.

U
1. Unicam Instruments Ltd., Cambridge.

V
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W
1. Wallace & Tiernan Ltd., London, W.4.
2. West Instruments Ltd., Brighton, Sussex.
3. White Electrical Instrument Co. Ltd., London, E.C.1.
4. W. H. Wilcox & Co. Ltd., London, S.E.1.
5. Alexander Wright Ltd., London, S.W.1.
6. Winston Electronics Ltd., Shepperton, Middx.

Z
1. G. H. Zeal Ltd., London, S.W.9.

AUTOMATIC CONTROL IN SOVIET SULPHURIC ACID FACTORIES

How Russian engineers are applying automatic control techniques to an important branch of the Russian chemical industry.

by SEMYON KUZNETSOV

MUCH work has been done in the Soviet Union in post-war years to step up sulphuric acid production. The increase in production has been brought about mainly by reconstructing the plants destroyed during the war, by the construction of new installations and by the overhauling and expanding of the production of the already-functioning enterprises. Simultaneously with the restoration, overhauling and construction of sulphuric acid factories, automation methods have been introduced.

At all the factories, wherever possible, complete automatic control has been provided for the process variables involved in the efficient performance of the units. Apart from this, the equipment installed includes remote control devices as well as individual automatic regulators. The new chemical enterprises and some of the completely overhauled factories have been provided with complete automation, all the facilities of automatic control and regulation being concentrated in one place, which, as a rule, is the office of the shift superintendent.

It should be noted that automatic control was not introduced overnight, nor completely. For example, even such a top priority task as automation of analytical control of processes has still to be completed. The main reason for this is the shortage of special and partly-standard instruments. Some of the special devices are either being evolved or tested industrially, and only recently has production been started on fog-meters, gas-analysers of sulphur dioxide traces, while dust-counters, arsenic analysers, nitrose counters and a number of other special devices are being developed or tested. This accounts for the fact that control chemical laboratories still exist even at the most up-to-date factories, which otherwise are adequately equipped with automatic control and regulation devices. The laboratories are engaged in analysing those parameters (mostly the composition at various stages of the process) for which no suitable devices have yet been developed. The laboratories also check at intervals some of the automatically controlled variables and control the composition of the initial raw materials, etc. In the designs of chemical establishments using automatic controls, provision has been made for a subsequent installation, when required, of similar or new devices. Hence, the addition of new devices to an existing automation system can be carried through readily.

In addition to automatic control of technological parameters, the efforts of the research workers and instrument builders have in the past few years been concentrated on all-out automation of contact sulphuric acid production, and, above all, of the major production units, such as kilns for sulphur-containing raw materials, contact apparatus and drying-absorption sections. The description of the most typical schemes of controlling the units and sections is given below.

Calcination of Sulphur-containing Raw Materials

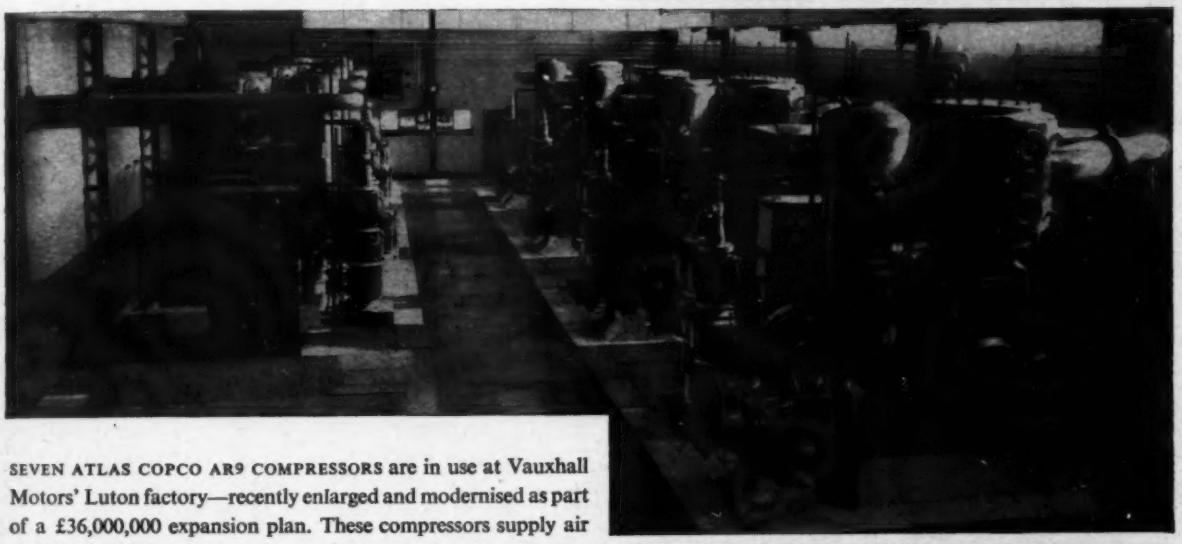
Most of the existing sulphuric acid plants are equipped with mechanical shelf kilns and pulverised calcination kilns. (The kilns of the latter type are somewhat fewer in number, and there are still fewer sulphur burners.) Since the mechanical furnaces are too small, which makes automation impractical, they are either being modernised or are being replaced by turbulent-layer-type furnaces.

Modernisation is proceeding along various lines: these include the building of new furnaces with a capacity of 200-300 tons a day, utilising the heat of the fluid and gases in conventional and uniflow boilers directly or indirectly by means of high-temperature heat-transfer agents. All the furnaces are designed for the utmost utilisation of their capacity and for a yield of high concentration gas and the newly-built or reconditioned furnaces are automatically controlled. The aim of automation is to ensure through highly efficient operation the production of a constant desired gas volume of specified composition.

Fig. 1 shows an automation diagram of a furnace for pyrite calcination by the fluid-bed process. As seen from the diagram, the furnace capacity is kept constant with the help of regulator R-1, which is used to control the quantity of air fed to the furnace. In some cases the regulator is corrected by the load indicator for the whole department. The concentration of sulphur dioxide is maintained constant by regulator R-3. The primary impulse is produced either by the thermo-conductometric gas analyser which measures the SO_2 content in the gas after the furnace, or by a thermo-

S. Kuznetsov *is Head of Automation Department, State Institute for Designing Factories of U.S.S.R. Chemical Industry, Moscow, U.S.S.R.*

Compressed Air at work in Vauxhall's Luton extension



SEVEN ATLAS COPCO AR9 COMPRESSORS are in use at Vauxhall Motors' Luton factory—recently enlarged and modernised as part of a £36,000,000 expansion plan. These compressors supply air to the body fabrication shops, press shops and other departments, providing power for clutch movements; resetting presses; mechanical handling; loading; welding; and mixing and spraying paint. In addition air is supplied for a number of pneumatic tools such as wrenches, grinders, drills and hoists.

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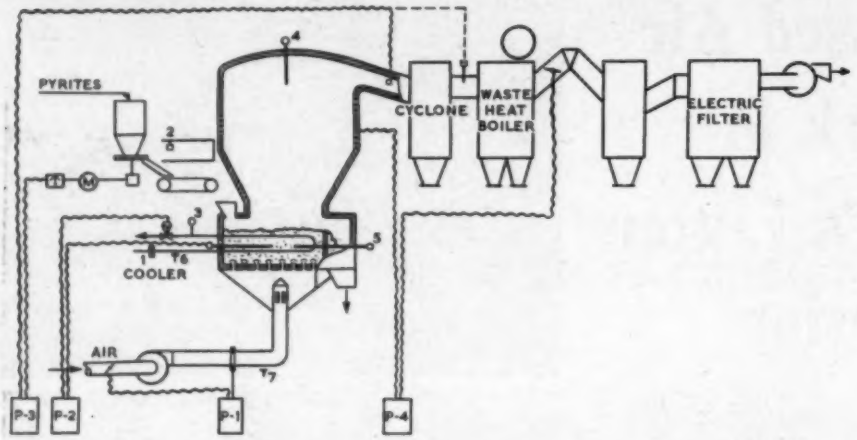

Fig. 1. Diagram showing controls necessary to automate a furnace for pyrite calcination by the fluid-bed process.

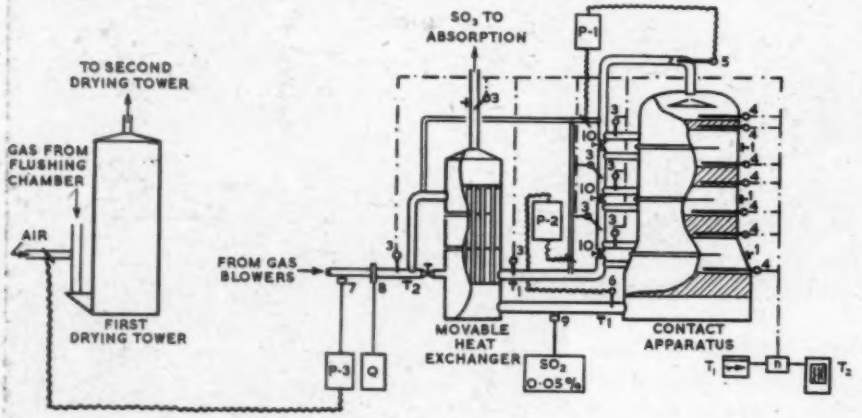

Fig. 2. A typical method of control layout for four-layer contact apparatus of the K-39 type.

couple measuring the gas temperature. Control is effected by changing the quantity of pyrites fed to the furnace.

Changes in the quantity of pyrite delivered to the furnace are affected either by the feed-table or the sectional feeder capable of changing smoothly the number of revolutions, or by feeder of the vibration type, whose amplitude of vibration can be varied. The total quantity of pyrite delivered to the furnace by the feeder is recorded by a weighing appliance (2). Draught in the furnace is kept constant by means of regulator P-4 acting on the controlling damper installed in the gas duct in front of the electric filter (or behind it). The fluid process temperature regulator (P-2) is installed when a high-temperature heat-transfer agent is employed or when it is necessary to co-ordinate the operation of the boiler and the cooling elements set up in the layer.

In addition to the automatic regulators, it is also proposed to control the temperature of the gas in the furnace (point 4), water (point 3) and fluid (at several points 5), the pressure at points 6 and 7, as well as the quantity of water supplied for cooling the fluid (point 1). Automatic feed to the boiler is effected by conventional means. All the devices and regulators are, as a rule, electronic; the regulators are pneumatic and are provided with special appliances whenever a switch-over to electric drive mechanisms, such as controlled drives of pyrite feeders, is required. Automation of pulverised calcination furnaces does not differ in principle from that of turbulent-layer furnaces.

Contact Unit

The contact sections of sulphuric acid plants have also received attention. Sulphuric acid factories operating on pyrites are mostly equipped with four-layer contact apparatus of the K-39 type with inside heat exchangers after the 1, 2 and 3 layers of the contact mass, and one or two detachable heat exchangers.

The conversion of sulphurous anhydride into sulphuric anhydride is best achieved, other factors being equal, by maintaining the optimum temperature of the apparatus while it is being constantly loaded with a gas of stable concentration. These requirements are met by the automatic regulators.

Fig. 2 shows a typical automation diagram of contact apparatus K 39. The temperature of the gas flowing into the apparatus is controlled by diluting the hot gas, heated in the detachable and inside heat exchangers of the apparatus, up to a temperature slightly above the one required by the process, by means of the cold gas selected before the detachable heat exchanger.

Control is effected by the electronic regulator of temperature (P-1) provided with a scale of 400-500°C, which operates jointly with the thermocouple (5) installed in the gas duct before its inlet in the apparatus. The accuracy of control is within ±1-2°C. Automatic control of the gas

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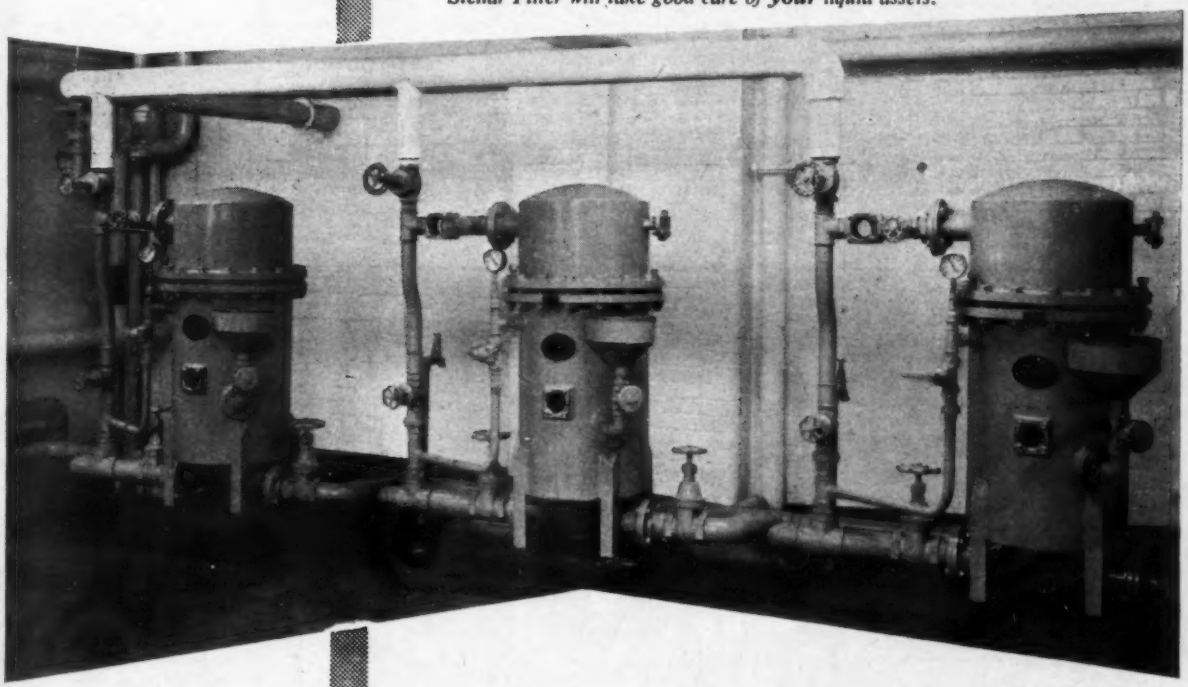

* *They may be: WAXES — OILS ESSENCES—WINES—SPIRITS JUICES—CHEMICALS PHARMACEUTICALS SYNTHETIC RESIN SOLUTIONS SOLVENTS—VARNISHES INDUSTRIAL FLUIDS—and, of course, WATER.*

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temperature is not required in the other layers of the apparatus, and the position of the dampers (10) to by-pass the gas from the riser to the inside heat exchangers of the apparatus, adjusted when putting the apparatus in operation, is seldom altered once the plant is in operation.

In some cases yet another temperature regulator (P-2) is installed to raise the percentage of contacting. The regulator controls the temperature of the gas entering the fourth layer by adding cold gas to the heat exchanger above the fourth layer of the apparatus. The concentration of the gas (about 7%) supplied for contacting is maintained constant by the concentration regulator (P-3). This is implemented by diluting a stronger gas, produced in the furnace section, with atmospheric air sucked into the system before the first drying tower. The amount of this air is regulated by a throttle valve controlled by an electronic regulator of gas concentration (P-3).

A thermo-conductometric gas analyser is used as a regulator transducer. It controls the concentration of gas flowing into the contact unit. Sometimes the control of the gas concentration is carried out by the temperature of the gas after the first layer of the contact apparatus. In this case the thermochemical effect of the catalytic reaction on the first layer serves as indicator of gas concentration.

Apart from the above automatic regulators, preparations are under way for the control of the following conditions:

Manometric conditions at points 1 by means of very simple instruments installed on the spot, and at point 2 by means of an instrument installed on the board.

Temperature conditions at points 3 outside the contact apparatus, in the gas ducts and the riser; at points 4, inside the apparatus above the layers of the contact mass and inside them. The number of thermocouples to be placed inside the contact apparatus depends on its diameter. As a rule, from 3 to 9 or more thermocouples are installed for every layer. The thermocouples installed in each layer also help to control indirectly the distribution of gas along the section of the apparatus.

The thermocouples placed at points 3 and 4 are connected through a switch-over appliance (M) either to the indicating device (T1) or the multi-point (6-12 points) electronic self-recorder (T2). Tracking appliances provided with signalling are to be set up shortly, instead of the conventional devices, to control the temperature of the contact apparatus.

Percentage of contacting at point 9 is controlled by measuring the residue (traces) of sulphurous gas after the contact apparatus. An automatic electrochemical gas analyser with a 0-0.5% scale is used for the measurement of SO_2 traces.

Drying and Absorbing Section. Fig. 3 shows a typical automation diagram of a drying and absorbing section of a sulphuric acid department operating either on pyrites or the waste gases at non-ferrous metal enterprises. The section is designed for the production of up to 70% of vitriol oil (93% H_2SO_4), the rest consisting of oleum (20% of free SO_3).

The scheme provides automatic control for acid concentration (see Fig. 4) in the cycles of the drying towers and absorbers (regulators P-1, P-2, P-3 and P-4), the level of the acids in the circulation collectors (regulators P-5, P-6, P-7 and P-8), and the delivery of vitriol oil to the warehouse according to plan (P-9).

Conductometric transducers of the through type, operating jointly with an a.c. standard electronic bridge with a pneumatic controlling appliance, are used as regulators of 93%, 95% and 98% H_2SO_4, and 20% oleum. The level of the acid in the circulation collectors is controlled by standard syphon manometers with a pneumatic controlling appliance. A pressure tube, immersed in the collector and coupled with its free end (by means of an impulse tube) to the manometer, is used as transducer regulator. Air is

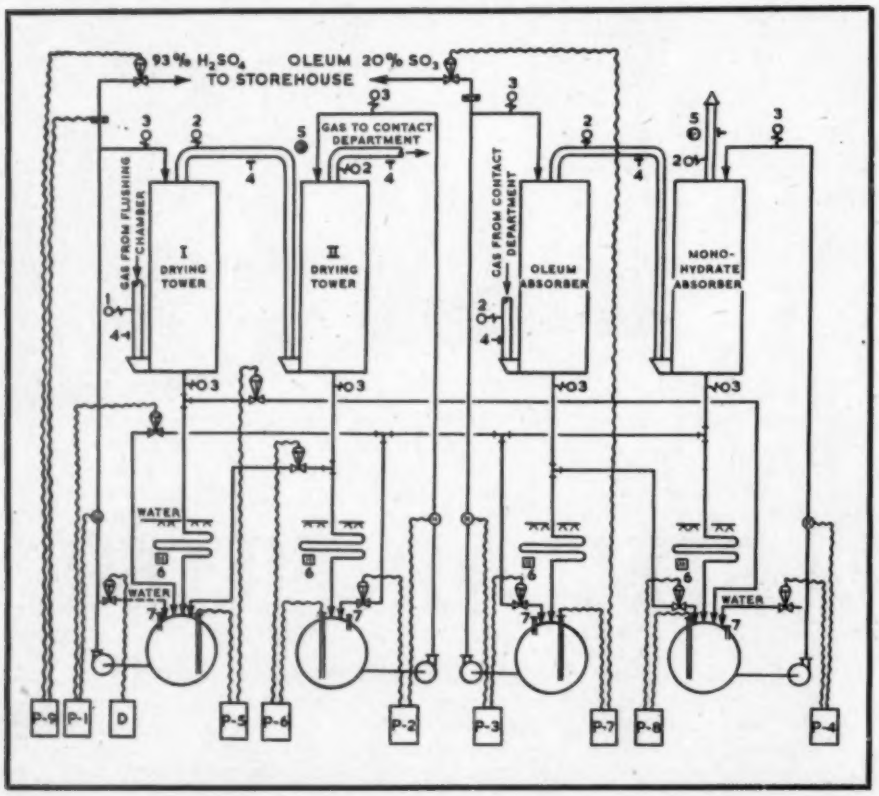

Fig. 3. Diagram of automatic controls necessary to automate a drying and absorbing section of a sulphuric acid plant.

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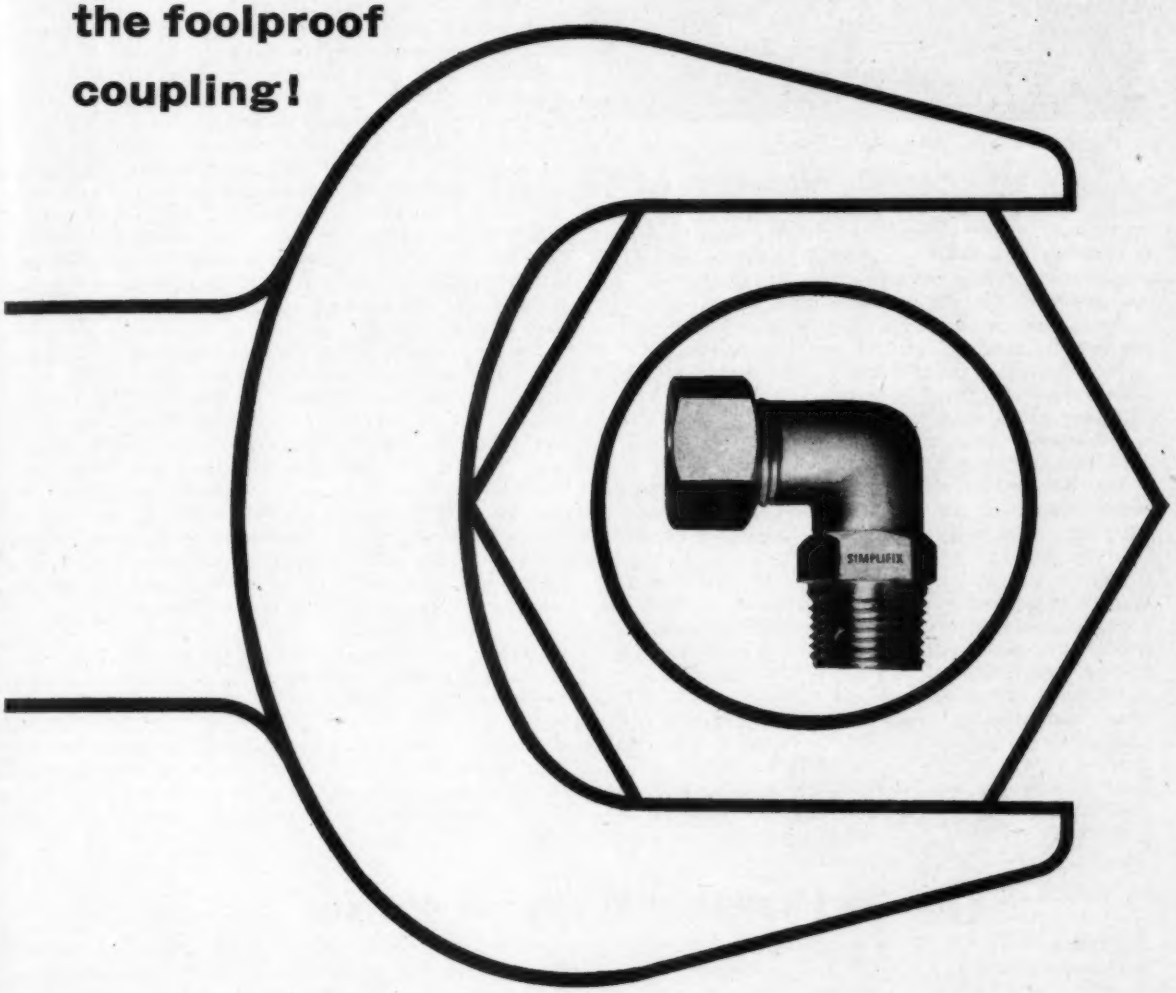

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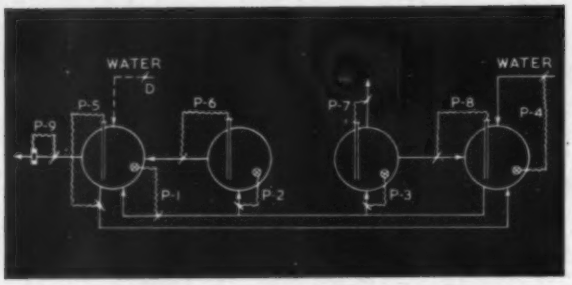


Fig. 4. Automatic control of acid-concentration, level of acids and delivery of oil to storage.

continuously blown through the tube. The finished product is obtained in a definite proportion with the aid of the regulator controlling the delivery of vitriol oil to storage, the surplus of the product being delivered as oleum.

Apart from the above-enumerated regulators, the following intended automatic controls are being introduced:

Temperature of gas at points 1 and 2 and of acid at 3.
Pressure and rarefaction at points 4; *fog* at 5.
Acidity of water in the trays of irrigation coolers at 6.
Maximum level in the circulation collectors at 7.
Quantity of oleum at point 8.

The temperature is controlled by resistance thermometers; theses are secondary instruments, a recording one for point 1, and an indicator with a change-over switch for the other points.

Pressure and suction are controlled by means of fluid draught gauges and manometers installed on the spot. The appearance of fog and its intensity are determined by photoelectric devices, and the acidity of water is controlled by its electric conductivity by means of a relay-type instrument; the maximum level of acid in the circulation collectors is controlled by means of ordinary electrodes and a relay scheme. The quantity of oleum delivered to the warehouse is controlled by a slit variable-level flowmeter provided with a secondary electronic device, and valves with a diaphragm pneumatic drive are used for the control of acid overflow.

Conclusion

The above schemes illustrate the scope of automation carried out at present at Soviet sulphuric acid factories. Naturally enough, the concrete schemes of individual technological processes of a similar type differ somewhat as far as details are concerned. Notably, when waste gases of non-ferrous metal works are used in the production of sulphuric acid, the gases often being of varying composition and quantity, the automation scheme requires additional appliances for a stable performance of the equipment. The automation scheme is, likewise, slightly modified when the gas of sulphur burners is used.

While the above systems of automation are being introduced in industry, research and experimental work is going apace to improve the special devices and simplify the systems of automation as a whole. The research is aimed at applying tracking devices, new radioactive instruments, television, etc., as well as computers to control the processes. It is thought, at present, that it will be advisable to employ the computers at factories operating on waste gases of a varying composition.

Some Economic Aspects. As a rule, the staffs at sulphuric acid factories are not numerous, even at those where automation has not been introduced. Hence no considerable saving is to be expected from curtailing the staffs. It is envisaged that, on completing automation and centralisation of control facilities, the sulphuric acid department (principally for safety reasons) should not keep more than two operators per shift. It is worth mentioning that, according to Soviet safety rules, many Soviet industries are not allowed to keep one person in a department. The departments operating on waste gases and using computing machines might release their staffs altogether.

As shown by the experience of many factories, the chief economic gain from introducing automation has been achieved by utilising raw materials to the full and increasing the life of the equipment through putting it to a more intensive use.

Research conducted at several automatically operated installations has proved that the expenditures on automation on the scope referred to above are repaid in six to twelve months, due to better utilisation of the raw materials and less waste.

Purification of Sulphurous Waters*

THE DEPOSITS OF SULPHUR discovered in Poland in 1953, between the Vistula and San rivers, in the Tarnobrzeg area, are likely to prove among the world's largest, with estimated resources of over 95 million tons of pure sulphur (average sulphur content of the ore is 29%). The combine based on them, which it is planned to build at Machow, will rank with that at Rozdola in the U.S.S.R. in scale; an output of a million tons of sulphur per annum is estimated as a likely figure for the mid-1970s. The Machow combine will embody an ore-processing plant, a sulphuric acid factory, a superphosphates factory, a cement works and plant producing inorganic salts. The first pure sulphur will probably be produced there in 1961.

Meantime, since the geological conditions are difficult, owing to saturation of the beds with water having a high concentration of hydrogen sulphide (up to 300 mg/l) and considerable salt content (up to 14 g/l including NaCl to 11.5 g/l), a pilot mine has been established on the left-bank section of the deposits, at Piaseczno, where the ore lies nearer the surface than at Machow, and work is now in progress on a preliminary ore-processing plant there.

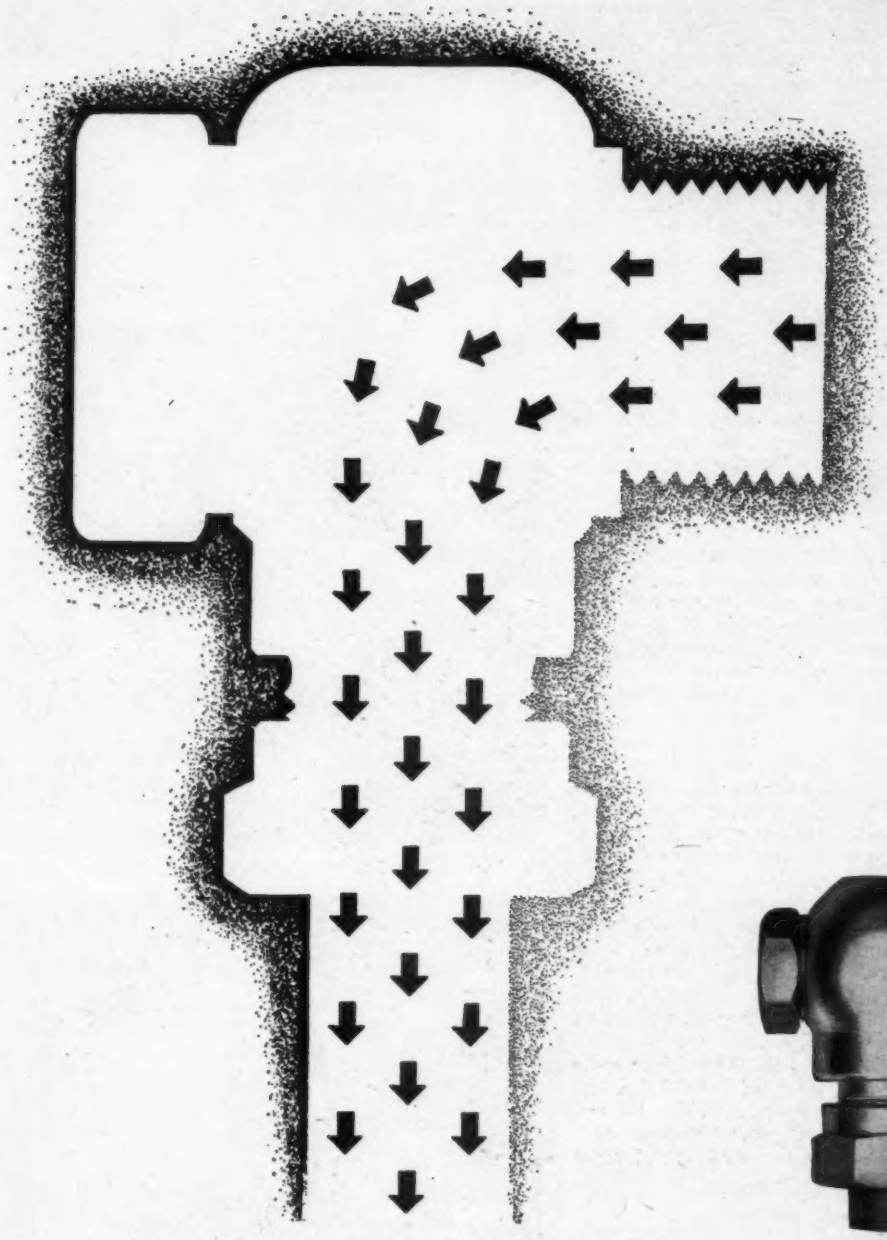
Two years' working experience at Piaseczno has provided useful data, especially on methods of drainage and water purification. The latter problem, which caused great anxiety, has been satisfactorily solved by reasonably simple means, and the water from the purification plant at the workings is almost free of hydrogen sulphide and may safely be released into the Vistula.

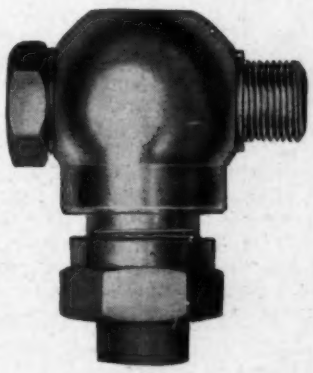
The contaminated water is pumped to the top of a packed tower, where air flowing in the opposite direction removes the hydrogen sulphide. The purified water is then led off into the river and the air containing hydrogen sulphide introduced into a second tower where it meets a counter-current alkaline solution of ferric hydroxide. In the first phase of the reaction hydrogen sulphide is absorbed by soda. The resulting acidic sodium hydrosulphide reacts immediately with ferric hydroxide, giving ferric sulphide which is then oxidised by atmospheric oxygen, producing ferric hydroxide and sulphur in a regenerative process:

$$2Fe_2S_3 + 3O_2 + 6H_2O = 4Fe(OH)_3 + 6S.$$

Sulphur is separated from the absorption mass by flotation and collected in the form of foam; it is then colloidally dispersed, to form a useful raw material for the production of colloidal hydrophilic sulphur for agriculture and the rubber industry.

*Condensed from an article by Dr. P. Hoffmann and Eng. K. Orzechowski in *Przeglad Techniczny*, 34, 1959.





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As evidence of the increase of industrial activity in Scotland, we present herewith a selection of new equipment of interest to chemical engineers which was displayed at the Third Scottish Industries Exhibition (see "British Chemical Engineering", November, 1959, issue, p. 608) held in the Kelvin Hall, Glasgow, on September 3. As was to be expected, a number of these items fell within the general category of pumps for a variety of applications.

CRAIG PUMPS LTD., of Giffnock, Glasgow, exhibited their new motor-driven diaphragm pump which has a high-speed pulsating short stroke which imposes the minimum stress on the diaphragm, the design of the valves being sufficiently light and positive to follow the high-speed operation while the inclusion of an air bottle sharpens up the performance and contributes to a steady discharge flow. The pump liquid end is constructed of a special ceramic which is said to be inert to practically all corrosive liquors—Craigs also state that, to the best of their knowledge, no other ceramic-lined, motor-driven diaphragm incorporating the above features is available in the United Kingdom. Standard capacity maximum is 350 gal./hr, although higher capacities can be catered for. A small hand-operated pump embodying the same constructional features of the motor-driven pump is also available.

The new John Clark (Rutherglen, Scotland) mixed-flow type pump (JCP-1) offers many features which will make it a useful pump for general applications in the chemical engineering field. These include high suction lift, self-priming and snoring characteristics and the ability to handle fluids containing up to 20% solid matter, coupled with a delivery of well over 80 gal./min. at 100-ft head. The 5½-hp electric motor is flameproofed. Hayward Tyler & Co. Ltd. (East Kilbride, Scotland), although not exhibiting the unit in question, stated that they are at present working on a new 10-hp glandless motor pump, the prototype of which is at present undergoing test at Harwell.

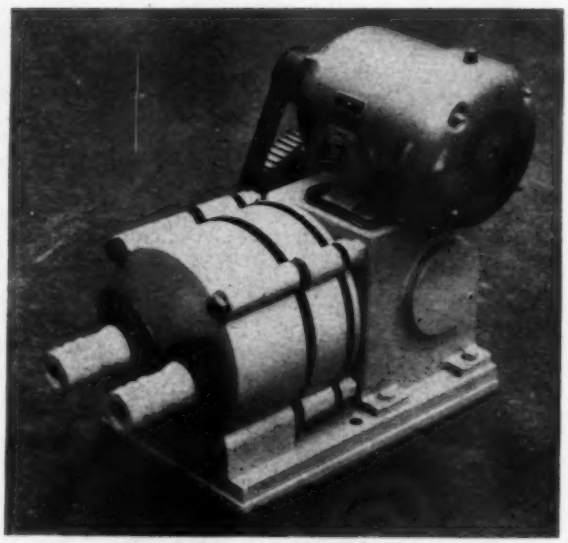

Fig. 1. The Craig motor-driven diaphragm pump.

Other Items of Interest

What has been claimed as a "break through" of major importance was a new material for unlubricated bearings (completely dry), which is based on P.T.F.E. The new material is available in various forms from Glacier Metal Co. Ltd., Kilmarnock, and can be used for bearing and thrust washers and as a bearing material capable of carrying heavy loads and operating at high speeds without the provision of external lubricants. A further material developed by the company is suitable for the manufacture of bearings by machining. This latter material, "DQ", is said to have outstanding wear-resistance properties.

A brushless alternator which has no brushes, no slip rings, no commutators and no external control gear was exhibited by the Macfarlane Engineering Co. Ltd., of Glasgow. All frictional surfaces have been eliminated by reducing moving parts to the combined rotor in its bearings only, so that freedom from wear and the absence of copper

Fig. 2. The Via-Vac mobile vacuum pump specially designed for the toggling of bar to plate and the fairing of plates.

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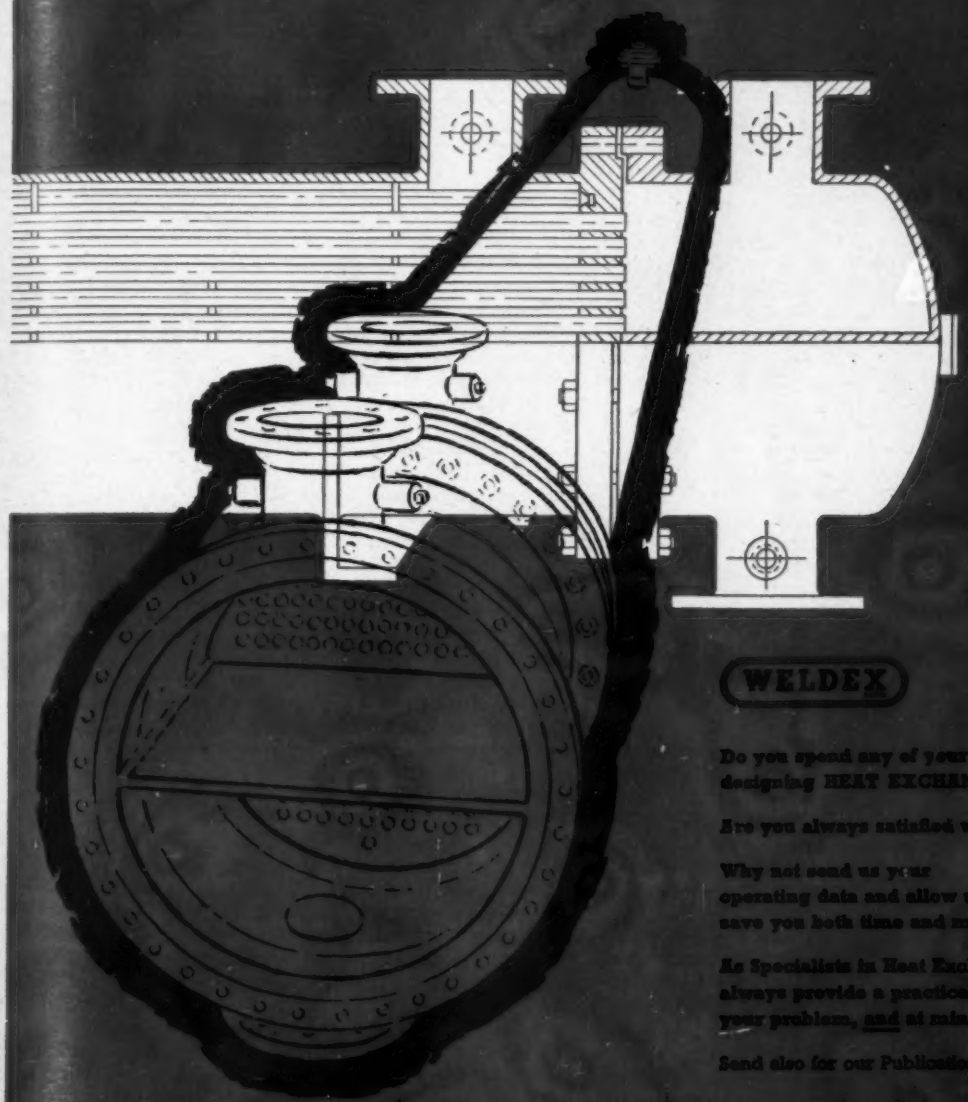

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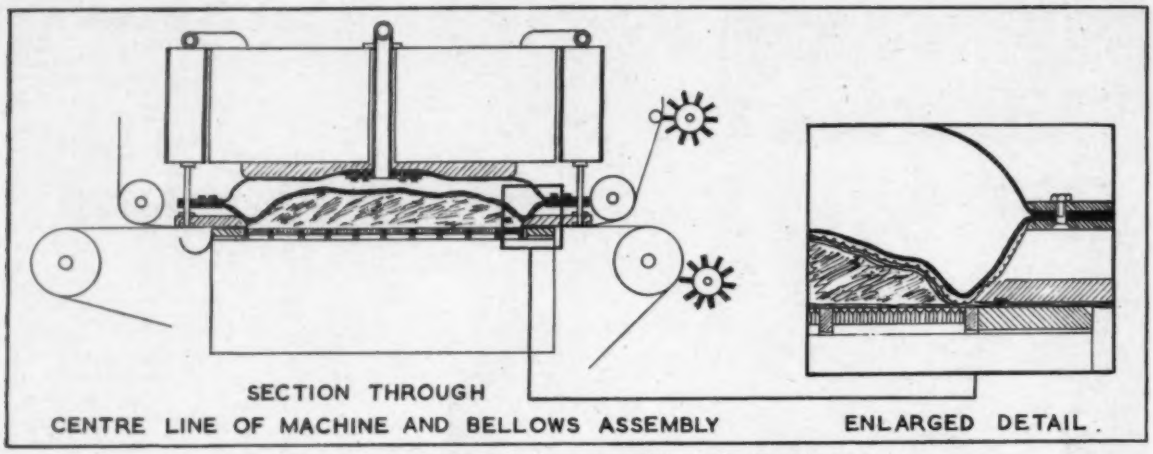


Fig. 3. Two views of the bellows assembly of the Davidson press.

and carbon dust, normally encountered in brushgear, greatly reduce maintenance costs. The alternator is of the revolving field, non-salient pole type. The supply to the field is from an exciter, which gives a three-phase output to rotating rectifiers. The output of the rectifiers supplies the main alternator field which is, in turn, supplied by a transistor pre-amplifier in conjunction with a Zener diode reference circuit. Both the rotating amplifier and the transistor amplifier are the subjects of patent applications.

A Davidson liquid extraction and filter press, originally developed for the automatic de-watering of wool but having since found other applications in industry, was exhibited by Sanderson & Murray Ltd., Galashiels, Scotland. The press is a fully automatic, self-feeding and self-discharging continuous press for all liquid/solid separations. It is suitable for organic and inorganic slurries, pulps and wet solids of all kinds. It combines pressure deliquoring of the solid part with fine filtration of the expressed liquid, the pressure range rising up to 30 atm. The press is available in two types, the S/S and the S/L. The former is for wet solids, pulps and mashes and the latter for slurries of from 1% solid content upwards. The principle of operation depends on the unique application of fluid pressure in a bellows, which allows total surface area filtration under standard conditions, the bellows being designed to operate at 450 psi.

Cockburns Ltd., of Cardonald, Glasgow, showed the stress-sealed butterfly valves they are now manufacturing under licence from the W. S. Rockwell Co. of America. This valve provides a close tight seal with a very narrow leakage tolerance under extreme conditions of temperature variation. The snug fit and tight seal are achieved by an externally supplied nitrogen gas pressure against a wide-alloy stress band welded peripherally into the valve body to form the seat for the disc. This gas inflates the band, closing the small gap between the seat and the disc.

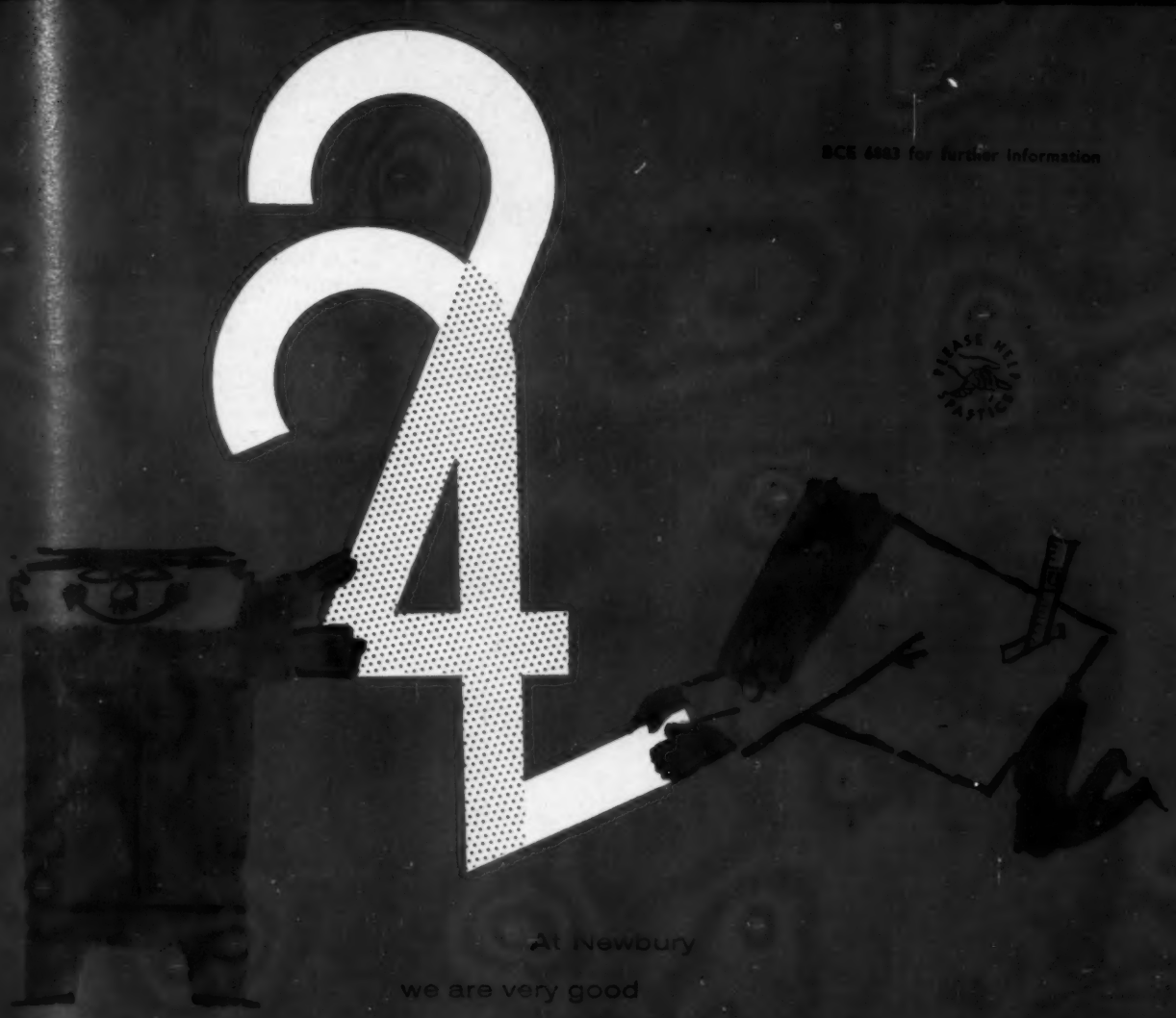
Impulse steam traps for extra light condensate load requirements, recently introduced by Dewrance & Co. Ltd. (Glasgow Road, Dumbarton, Scotland) for draining steam mains, steam headers, steam supply lines, steam-jacketed pumps, etc. The steam trap (No. 990) is furnished with ¼-in. screwed end connections and has a pressure range of from 8 to 600 psi, maximum temperature 750°F. The trap is small in size, light in weight, has only one moving part, a replaceable valve-seat assembly and a stainless-steel body and working parts for long service life.

What has been claimed as the most advanced method of handling a great variety of materials and yet is simple to operate is the Vac-U-Lift equipment manufactured by Vac-U-Lift (Great Britain) Ltd. (West George Street, Glasgow, C.2). The equipment is designed to lift any load and eliminates blocks, pinchbars, etc., and to lift the top plate only. The equipment is powered by a power pack for full operational control and is equipped with a special patented solenoid multiple-way valve, the system giving vacuum for attachment and compressed air for full and complete detachment from the material. Although the equipment will mostly be used for handling flat sheets, plates, angles, channels, etc., it is also readily adaptable to curved surfaces. It also gives equal results on any non-porous material to which the Vac-u-Pad can be attached. The Vac-U-Pads are manufactured in many sizes and shapes to adapt them to practically any use. Single pads are designed to lift from 25 to 5000 lb.

The Railway Division of the Pressed Steel Co. Ltd. (Paisley, Renfrewshire, Scotland) introduced for the first time, admittedly in model form, their new Railvan, which, to quote a spokesman of the company, is the rail vehicle of the future. The Railvan is a combination freight vehicle designed for use both on roads as an individual trailer and also in long trains on railway tracks. The inherent advantages of this design are said to be that the handling of freight is reduced to an absolute minimum and a more rapid service can be obtained, particularly when transfer yards are situated in high-density traffic areas. The vehicle is said, therefore, to open up vast possibilities for highly efficient door-to-door freight service. The unit consists of a set of retractable rail wheels and road wheels located at the rear of the trailer, suspended upon a torsional rubber spring element to give a smooth ride under all conditions. The wheels are retracted individually by means of a screw mechanism operated by compressed air, which enables the wheels to be changed over in a matter of seconds. Disc brakes are incorporated into the design to give maximum retardation, while the size of the Railvan makes it suitable for a load capacity of 11 tons and for use in any city.

The British Refrasil Co. Ltd., of Stillington, Co. Durham, introduced the Rostenit process for stainless-steel lining at the Exhibition. The process has been developed to provide reliable stainless-steel sheet linings for tanks and vessels that would normally have to be made entirely of stainless steel. It is said to greatly reduce the cost of installations where stainless is essential, and makes its use possible for processes where it would normally be too expensive. The Rostenit process involves covering the surface to be protected with thin sheets of stainless-steel argon-arc welded at the joints and edges to form a guaranteed impervious lining. The sheets can be of stainless-steel alloys in sheets 3 ft wide and 0·020 in. or 0·030 in. thick. Dockyard Co. Ltd., Irvine, Ayrshire displayed the Rostenit process.

BCE 6883 for further information



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AMERICAN LETTER

27th American Chemical Exposition

THE 27th Exposition of Chemical Industries held in the New York Coliseum, November 30 to December 4, was the largest chemical exposition ever held and great interest was shown in the exhibits of new chemical substances, while improved materials and more efficient machinery were more numerous than ever before. More than 500 displays filled four floors of the Coliseum.

Parental organisations of the leading "families" of chemicals were well represented and their approach to the 1960 market was voiced by a representative of one of them, who said: "Resins offered designers of these products just the combination of properties they had been looking for. The result is eight new plastic products that never existed before." Plastics are contributing bravely to the evolution of design and several new varieties, with their derivatives, were introduced at the Exposition. Evidences of the changes that plastics have wrought were abundant. Among displays, in addition to plastic pipe, valves and fittings, were pumps, blowers, mixers and other equipment featuring plastic components. Plastic coating materials were also much in evidence, as were linings and working parts of similar equipment having plastic impregnations of fabrics and laminates.

Plastics are commonly regarded as intermediates, rather than structural materials, but a number of exhibits suggested that a break-through into the wider structural field may soon be forthcoming. In addition to the familiar pipe and fittings of rigid plastics, an air washer was shown fabricated entirely of the polyvinyl chloride, as were plastic reinforced tanks and shipping drums without reinforcement. A line of laboratory sinks in cast epoxy resin also made its appearance.

Shown for the first time was a line of flexible plastic pipe and a high-pressure hose without metallic or other reinforcement, which was demonstrated in flexure-testing rotation at high speed, under pressure of 2000 psi. New, too, were a number of applications of ceramic linings and working parts for pumps, exhausters, reaction pressure vessels and valves. Similar equipment was shown with impervious graphite linings and parts, also fans made of polyester fiberglass.

In the kindred field of glass there were exhibits of a lining for vessels, reactors, storage tanks and rotary dryer-blenders, and said to be the most corrosion-resistant glass ever applied to steel products for the chemical industry. Another exhibit introduced a new boro-silicate glass lining for steel pipe, more than twice the thickness of glass linings previously produced. The varied methods of protecting chemical processing equipment from the ravages of corrosive and eroding materials reflect the present position of chemical engineering in its course of evolution.

In spirit and experimentally, the chemical process industries are far ahead of even this year's newest products. Evidence in point was the presentation at the Exposition of laboratory and pilot-plant equipment for work in the extremely high-pressure range. Few, except nuclear and missile activities, are in that realm at present. High-pressure equipment on view included valves, pumps and other items. One manufacturer has turned out a four-stage compressor for work in nucleonics that will raise a pressure of 35,000 psi, but another offered to produce equipment to handle 100,000 psi to order.

At the opposite extreme, intrepid researchers are working in cryogenics, heretofore more or less an abstraction familiar to scientists, but limited in application. As the properties are modified under high heat and pressure, so also they change in the absence of heat and pressure. One cryogenerator at the Coliseum was designed to operate in a range of 330°F below the ambient temperature. Some of its applications, it was said, might be in accelerated ageing and stabilisation of metals, cold machining of soft materials, which could not be worked at normal temperatures, or research in solid state devices—such as infra-red detectors, masers and cryotrons—in food storage, preservation of biologicals, and, of course, in the further reaches of cryogenic research. Another exhibitor of similar equipment offered as one of the more important phases of the cryogenic technique the separation of gas mixtures containing two or more major components into separate high-purity products of commercial value.

Because the chemical industries are never far from the laboratory, the Exposition offered many displays of new and improved instrumentation, as well as laboratory equipment. The impact of the instrument displays, however, was more directly in line with the current trend toward teaming instruments of laboratory quality with sensing devices, on the one hand, and controlling devices, on the other, to accomplish automation. Automation reached its peak in the display of the first computer ever designed to exercise completely automatic control over a petrochemical plant. This display represented a major project in itself and a landmark in industrial development.

Several other system, plant or process control exhibits were on view, ranging from single-purpose instruments to complete scanning and regulating systems. The essence of automation as an accommodation for industry at large, however, found expression in a "compatible" transmitter, said to be applicable with any motion input and any signal output. Many single-purpose instruments and other devices were shown that are compatible with planned improvements to existing plant controls.

One such was an industrial gas chromatograph for the analysis of multiple-component streams. Another automatically carries out wet chemical analyses and records the data on a continuous chart.

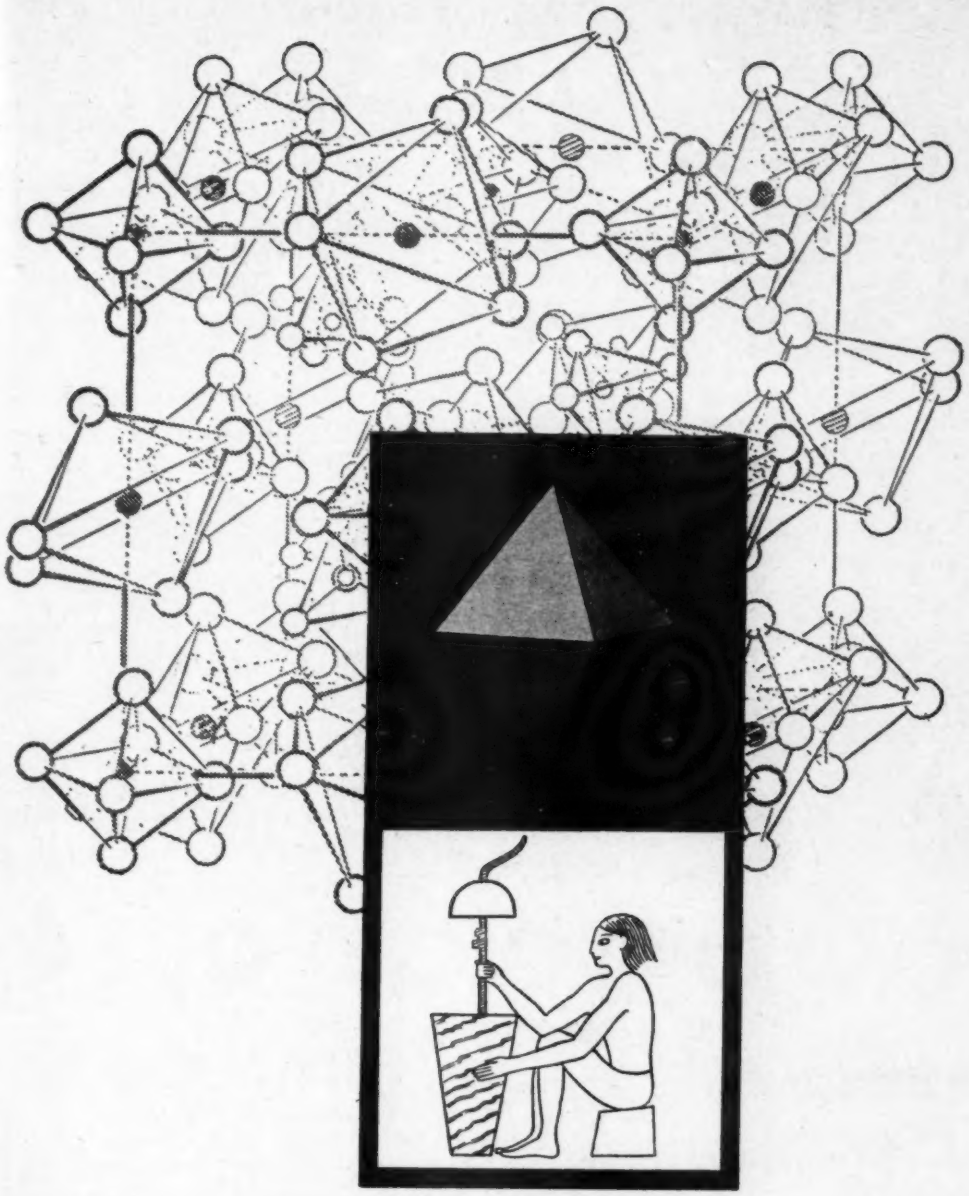
The Exposition produced many examples of sophisticated design. A tiny chemical feed pump was enblocked in a clear plastic case, permitting its operation to be observed. A free piston pump had no moving parts except the pistons and, it was said, would pump anything that would flow.

A heat exchanger, capable of performing a wide range of fluid and vapour cooling functions was air cooled A "completely corrosion-resistant" heat exchanger was constructed entirely of impervious graphite.

Designed to head off the air pollution problem in industrial plants was a dust filter in which glass marbles formed the filter bed. Offered in this country for the first time was a centrifuge of Swiss origin designed to handle difficult materials. Its multi-stage construction is unique.

Among imaginative developments was the application of catalytic combustion to industrial fume control—another of the several methods offered to reduce the public nuisance stigma from which industrial plants often suffer.

Vibrators have been applied to a variety of equipment to prevent the clogging of sticky materials, but one was designed to accomplish the same end without shaking the entire machine or any part of it.



The earliest chemical industry

Alum has been manufactured by Spence for over 100 years. It is one of the oldest chemicals used by mankind; indeed there are references which go back 4,000 years. In addition to being one of the largest manufacturers of alum and aluminium sulphate for paper making and water purification Spence are also producers of catalysts for petroleum refining and organic titanium compounds for the paint, plastic and textile industries.

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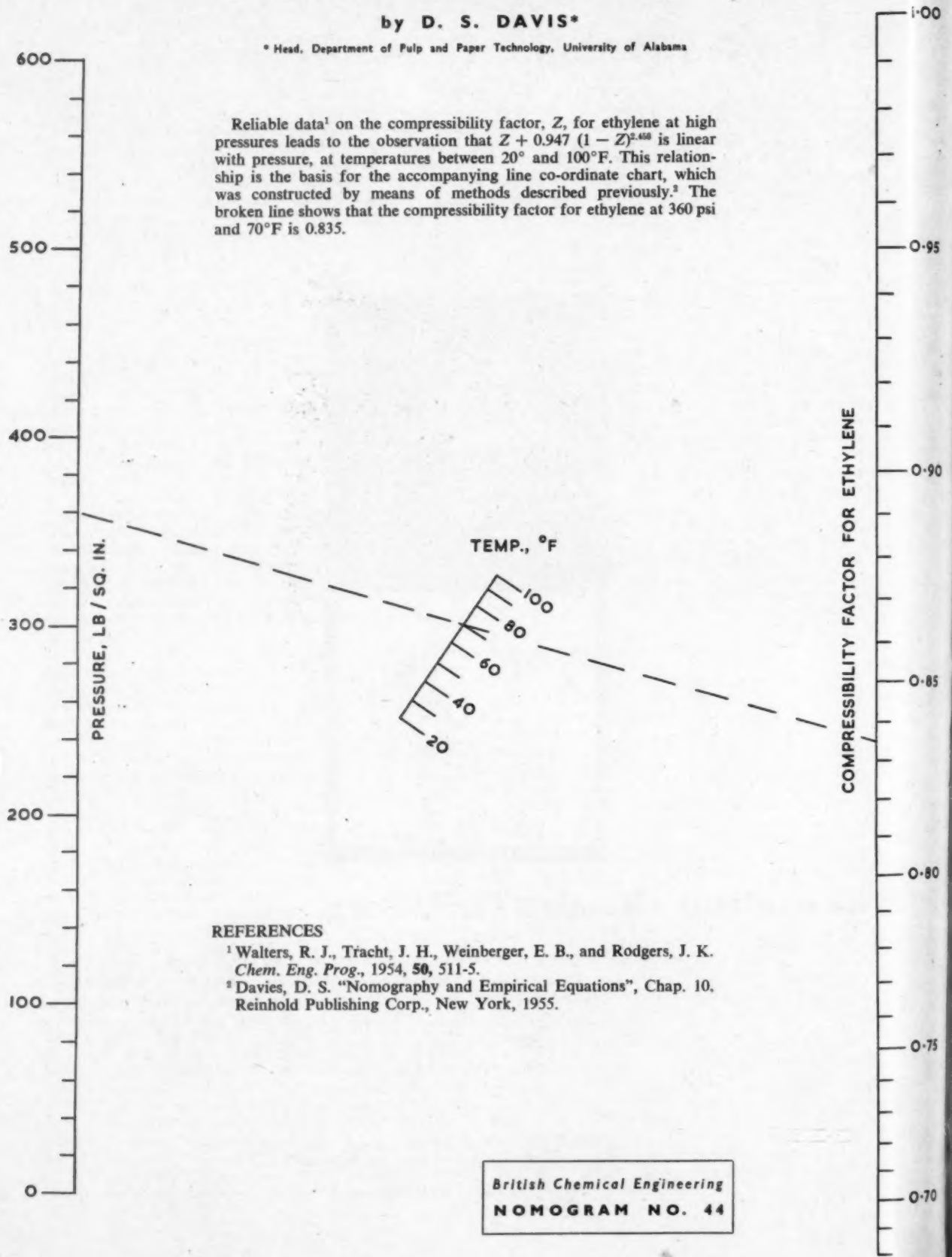
NOMOGRAM SHOWING COMPRESSIBILITY FACTORS FOR ETHYLENE AT HIGH PRESSURES

by D. S. DAVIS*

* Head, Department of Pulp and Paper Technology, University of Alabama

Reliable data[1] on the compressibility factor, Z, for ethylene at high pressures leads to the observation that $Z + 0.947\ (1 - Z)^{2.455}$ is linear with pressure, at temperatures between 20° and 100°F. This relationship is the basis for the accompanying line co-ordinate chart, which was constructed by means of methods described previously.[2] The broken line shows that the compressibility factor for ethylene at 360 psi and 70°F is 0.835.



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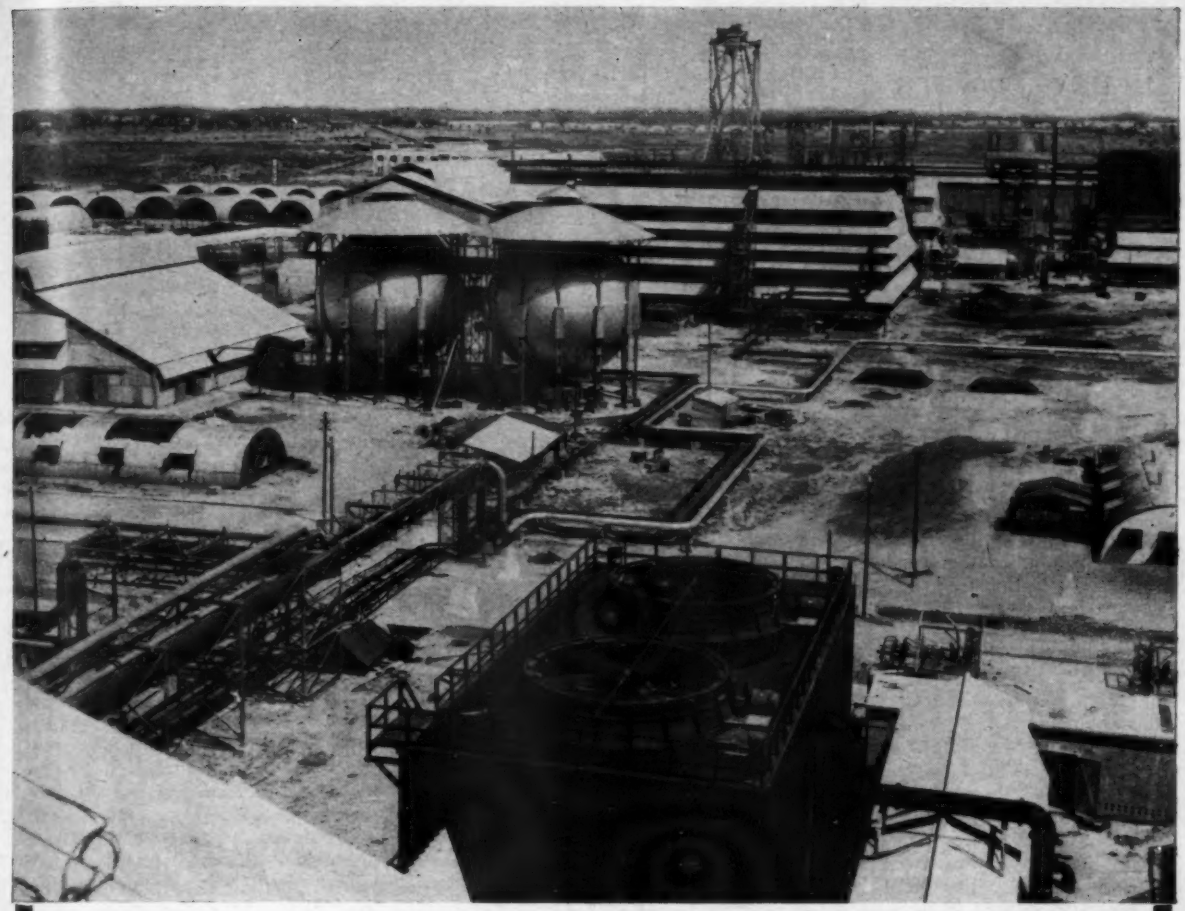
[1] Walters, R. J., Tracht, J. H., Weinberger, E. B., and Rodgers, J. K. *Chem. Eng. Prog.*, 1954, **50**, 511-5.

[2] Davies, D. S. "Nomography and Empirical Equations", Chap. 10. Reinhold Publishing Corp., New York, 1955.

British Chemical Engineering
NOMOGRAM NO. 44



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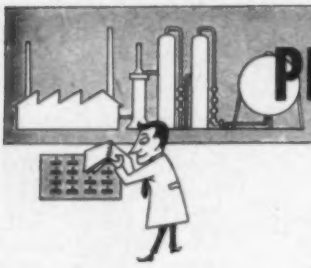
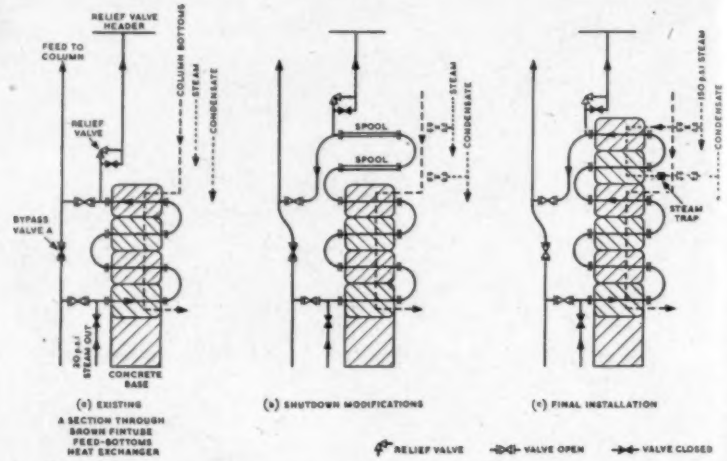


PROCESS ENGINEER'S NOTEBOOK

Making Modifications to Continuous Processes

THE FOLLOWING IS an example of one of the techniques used to permit modifications to continuous processing chemical plants with the minimum loss of production. In this particular refining plant the feed to the de-isobutaniser columns was preheated by exchange of heat of the column bottom product by means of a Brown fin-tube exchanger consisting of four hairpin sections as shown diagrammatically in Fig. 1 (a). Because of changes in process flow conditions, it became necessary to install an additional steam preheater in the feed line. The simplest solution appeared to be to add two Brown fin-tube sections to the existing four sections. Since the plant operates continuously, it was necessary to plan the work at the next scheduled shut-down of the plant, an operation conducted annually. As it happened, the two additional fin tubes required could not be delivered in time for the scheduled shut-down and it was impossible to defer this without dislocating the shut-down schedules for other units of the plant. This difficulty was overcome by making certain modifications when the scheduled shut-down took place.



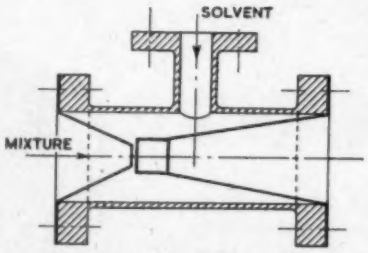
These are shown in Fig. 1 (b) and they allowed the installation of the additional fin tubes to be made at a later date while the plant was still in operation.

These modifications consisted of relocation of the relevant valve, installing stubs and valves in the existing steam condensate lines, installing return bend assemblies and interconnecting spools as shown in Fig. 1 (b). On plant start-up after the shut-down the plant was operated as previously. When the two additional fin-tube sections had been delivered the feed to the column was by-passed by the two additional fin-tube sections and the 100 psi condensate tie-ins were made. The complete heat-exchanger unit was then purged of air by steaming from the 20 psi steam line into the relief valve header by way of the relief valve by-pass valve.

When steaming out was complete, the exchanger was isolated from the low-pressure steam supply and from the relief valve header, and by-pass valve A was closed. The unit was then operated according to the scheme shown diagrammatically in Fig. 1 (c). Although it was necessary to reduce column through-put during the time required to remove the spools, install the new section and steam-out the exchanger, the above method eliminated the need for a column shut-down which would have required the steaming out of the column as well as a major loss in production. The above procedure illustrates an approach that could be used on continuous processing plants when new equipment deliveries do not coincide with scheduled plant shut-downs.

A Simple Venturi Mixer

THE IMPORTANCE OF SECURING adequate liquid mixing has been frequently stressed in the literature and, in particular, the economics and efficiency of jet mixing for the blending of oils and chemicals has been thoroughly explored. This liquid mixing operation is of fundamental importance in liquid/liquid extraction, since the major mass transfer takes place at this stage. In an investigation on the use of hydrocyclones in solvent extraction, it was necessary to use a line mixer for continuous mixing of solvent and feed and the combination of jet mixer and entrainer, in the form of a simple venturi mixer as sketched.



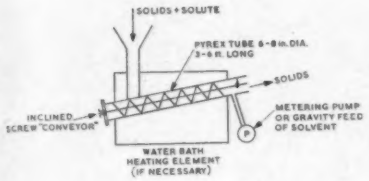
A SIMPLE VENTURI MIXER

was developed. This consisted of a flanged unequal cast-iron tee fitted with a short convergent nozzle in 22 S.W.G. stainless-steel sheet and a divergent expansion nozzle in the same material. It was found that operating in conjunction with the hydroclone, although the mixing was satisfactory there was little pressure drop in the venturi mixer itself, leaving almost the whole of the pressure head available for the separation of extract and raffinate as overflow and underflow respectively in the hydroclone.

F. MOLYNEUX

Home made Pilot Plant Extractor

THIS EXTRACTOR IS particularly suitable for solids of low specific gravity and having a definite particle shape or for fibrous material. Its main components are an inclined screw conveyor working inside a closed tube. The conveyor tube is submerged in a waterbath provided with some form of heating if heat is required to assist the extraction process. The Pyrex glass tube is readily available and permits observation of the process. The metering pump, by varying its capacity, permits a study of the optimum solvent-solute ratio for a constant flow of material transported by the screw. On a larger scale, however, a different material of construction might be necessary. Nevertheless, the use of glass makes it possible to explore all the variables, contact time, solvent-solute ratio, temperature of waterbath in relation to boiling point of the solvent and so on. This extractor was observed at a fish-meal extraction plant in Nova Scotia.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Reflux Regulator Convenient for Laboratory or Pilot-plant Investigations

THE REFLUX REGULATOR described here is very convenient for laboratory and pilot-plant investigations. The regulation of the reflux can be accomplished very accurately at will.

Equipment and its working: The equipment is made of glass and is of Quickfit type. The funnel below the condenser is mounted on a pivot (see diagram). It carries a soft iron piece embedded in a glass tube The soft iron rod is attracted by means of an electro-magnet which is operated by electronic switch. When the soft iron rod is attracted, the funnel changes its position in such a way that the condensed vapours flow into the funnel connecting distillate outlet. While in the normal position, condensed vapours flow to the distillation column.

The electronic device has a dial having graduations from 0 to 100. The dial completes one revolution in $\frac{1}{2}$ or 1 min. By setting the pointer on any number, reflux ratio can be altered, e.g., when the pointer is set on 20, the soft iron rod will be attracted for 20% of the time taken by the dial to complete one revolution. Thus 20% of condensed vapours will come out as distillate and 80% of them will return to the column.

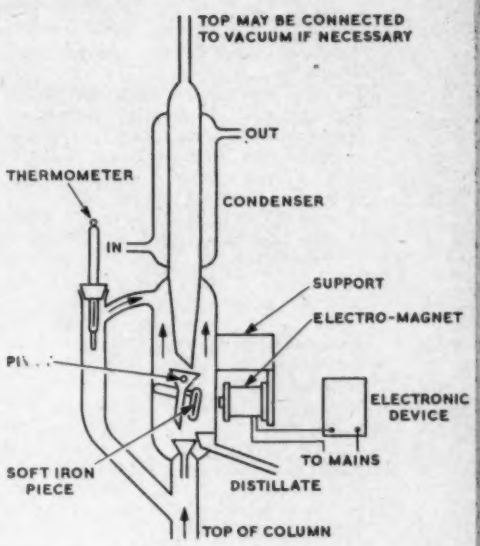
Reflux ratio will be therefore

$$R = \frac{80}{20} = 4.$$

Advantages of this reflux regulator are as follows:

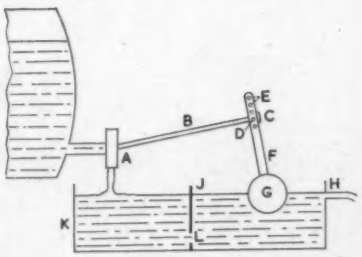
(1) it is easy to control the reflux ratio accurately;
(2) for total reflux, the electronic device need not be used;
(3) distillation may be done at reduced pressure with certain modifications in the equipment. Quickfit assembly makes it possible to set up these modifications easily when required; and
(4) once the reflux ratio is adjusted, no supervision is required.

M. S. TENDULKAR



Inexpensive Means of Controlling Rate of Flow of Liquids

THE ACCOMPANYING DIAGRAM indicates an inexpensive means of controlling the flow rate of a liquid from either a storage or process vessel. The device consists essentially of a modified float valve, A, delivering the liquid to a rectangular tank, K, fitted with a V-notch weir, H. The flow rate from tank K is dependent on the height of the liquid above the apex of the V-notch and this, in turn, is controlled by the position of the float, G. Calibration can be carried out either by calculation or by direct measurement and linkage arm F drilled in several positions, E, accordingly. Linkage arm B is fitted with a stud, D, locating with hole E, and the angle between the two arms is fixed by a T-piece, C, welded at right angles to arm B. In order to obviate the effect of surface waves on the stability of the float, a transverse baffle, J, is fitted, the free space, L, so chosen as to provide negligible resistance to flow. This device has been used with marked success in industry, where it has been found to control to within fine limits.



J.F.G

Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

Book Reviews

Fluidisation
by Max Leva
McGraw-Hill Book Co. Ltd., London, 1959, 327 pp., 89s.

IN the two decades since fluidisation emerged as a chemical engineering operation in its own rights, a plethora of papers has been published, and new work is appearing at a rate that tends to make a text-book on this subject out of date almost before it leaves the press. On the other hand, this very profusion of information has created a pressing need for a reference work which can serve as a comprehensive bibliography of fluidisation; classifying, co-ordinating and correlating the published work, without necessarily attempting to draw independent conclusions. Such a treatise would be dated, but never out of date.

The present work, by an author who was an early pioneer in this field, goes some way towards fulfilling that need. The preface states: "The book is designed to serve both as a reference volume for practising engineers and as a supplementary text for students of the unit operations in chemical engineering." Students of general chemical engineering, however, should have no time for works of this nature and would be better advised to confine their study of fluidisation to the relevant chapters in such books as Coulson and Richardson, or Smith and McCabe. From the viewpoint of practising engineers as well as research workers in this field, however, this is a most useful work.

The book comprises an historical introduction and nine chapters, each covering a different aspect of fluidisation. Most of the chapters commendably commence with an abstract and a list of symbols relevant to that chapter. Worked examples are given and six chapters conclude with set problems, the value of which would have been greater if the answers had been added. With some elementary descriptive matter and postulates, it assumes part of the character of a teaching book and loses valuable space which could have been more usefully devoted to increasing the number of references.

Much of the research in this field has been concerned with the development of empirical equations to correlate experimental findings. This book deals largely with such correlations, which undoubtedly can prove useful in indicating trends and giving guidance towards design.

From the profusion of fluidisation literature, it has been necessary to select, and therefore to omit. The papers quoted (some 200) are fairly representative, but some have been given undue weight, and it was a pity to have to omit reference to papers such as that of H. M. Katz on particle size distribution in fluidised beds.

The author follows the accepted belief that channelling is anomalous behaviour in fluidisation, and devotes a short chapter to a recent technique, "Spouting", which is an extreme form of induced single channelling. The reviewer's own observations suggest that channelling may perhaps be an integral part of the fluidisation mechanism. He has always found movement of particle beds (other than slug or piston movement) to initiate by virtue of channels in the bed. Logical reasoning will conclude that for incompressible fluids this must necessarily be the case, and that smooth expansion from the fixed bed is more apparent than real.

The recent tendency is for a more scientific approach to fluidisation and for point-to-point study in fluidised beds. Study of the movement of individual bubbles, improved methods and new techniques may show that the accepted picture of fluidisation is out of focus.

The reviewer cannot help drawing the attention of American authors to their occasional debasing of the English language by giving new and incorrect usages to words quite unnecessarily. The use of "spectrum" for size range, or range of phenomena is an example.

If the next edition of this book is designed solely for advanced workers in the field, and the list of references widened and brought up to date, this work could become a classic. Even with its present shortcomings, it is thoroughly recommended as a reference book on fluidisation.

N. J. HASSETT

The Corrosion of Chemical Apparatus
by G. L. Shvartz and M. M. Kristal
Chapman & Hall, London, 1959, 250 pp., 60s.

THIS book is rather typical of the translated Russian texts on technological subjects that are now becoming available. The translation is accurate, and so reflects the tone of such books, of being a manual aimed at the practising engineer or scientist in industry. One imagines that such works are the result of a deliberate policy of causing research specialists to review their field and to set out a digest of the available information interpreted in the light of their own work. Although pedants might challenge the style of the result, its effectiveness is usually undeniable.

This is true of the present case, where despite the general title the specialised field of corrosion cracking is treated in this fashion. Following upon a brief but intelligible statement of the theoretical position, much detailed information is given on corrosion cracking of carbon steels, stainless steels and some non-ferrous metals. About one half of the frequent references are to Russian sources, but the authors frequently introduce their own observations and unpublished results. Nor are they fearful of stepping into the rocky grounds of prevention and testing, although their industrial colleagues may echo the plaint of their western counterparts that outright recommendations are few!

The style is a little difficult for continuous reading, for many sections are a series of brief statements of fact without much conjoining reasoning. Nevertheless, some of the material will be new to British readers, and its collection in one volume is useful. The substitution of a table of contents for an index is no obstacle to finding the information available on any material of construction.

T. K. Ross

The Design and Construction of High-pressure Chemical Plant, 2nd Edition
by H. Tongue
Chapman & Hall, London, 1959, 250 pp., 84s.

SO many developments have taken place in the techniques of high-pressure chemical plant over the past 25 years that the author faced a formidable task in revising his book first published in 1934. On the whole this has been successfully accomplished and the second edition is virtually a new book on the subject concerned. For example, the introductory chapter concludes with a review of the developments of high-pressure requirements in the nuclear energy field. In referring to Codes of Practice it is unfortunate that the second edition had to go to press leaving references to B.S. 1500: 1949, which has been replaced by B.S. 1500: 1958 with considerable modifications.

Much fundamental work both of a theoretical and experimental nature has recently been undertaken by various investigators to place the design of cylindrical vessels under pressure on a reliable basis. This work, concerned with stress distribution and bursting pressures, is scattered in various technical publications. The collection of much of this work into a single chapter will be welcomed. The alignment charts for thermal stress seem out of place in this chapter. There are more convenient methods of indicating thermal stress diagrammatically. Also, less significance now tends to be attached to thermal stresses, unless they are sufficient to give rise to plastic strain.

The chapters on auto-frettage and compound cylinders bring the reader up to date on these practices. A chapter is devoted to the manufacture of pressure vessels by fusion welding and of clad form of construction. Most of the consideration given to flanged closures for pressure vessels relates to those for medium-pressure vessels, and little to closures for the higher pressure vessels. The latter could with advantage have been expanded at the expense of the former, which will already be familiar to designers of chemical plant.

Much recent information is included relating to materials under high-temperature conditions. That relating to materials exposed to low temperatures, however, contains little reference to recent work on the subject. This is surprising in view of the extensive work carried out since the war on brittle fracture at low temperatures. The importance which is now attached to the stress-relieving of mild steel when used for low-temperature service is not mentioned in the factors affecting the low-temperature behaviour of ferritic steels.

The later chapters of the book contain some very interesting and up-to-date information concerning the details of pumps and compressors, various types of autoclaves, pipework, valves and fittings. Descriptions are given of the techniques employed in the preparation and purification of industrial gases and

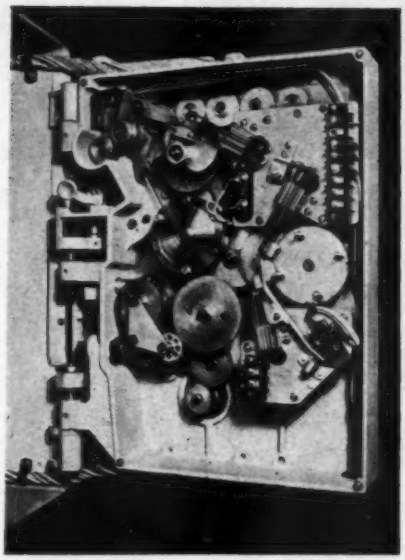
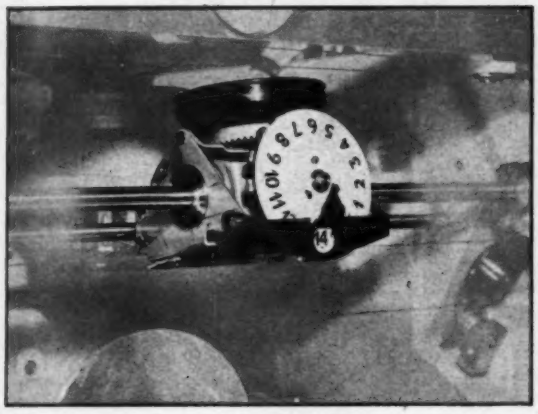


Chart-drive gear train and multi-point mechanism

This new *mark 3* electronic *multelec* recorder—



Multi-point printing mechanism with self-lubricating pen-carriage unit

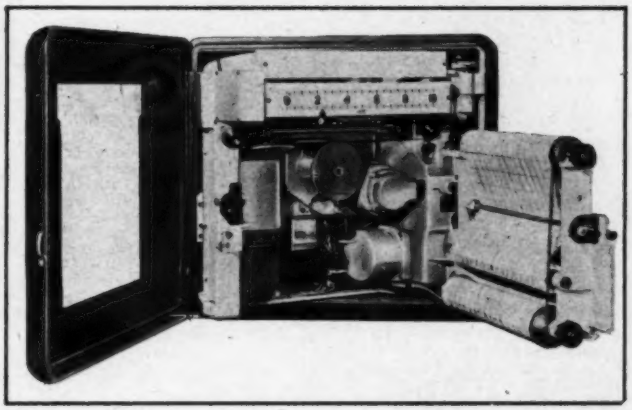


Chart frame swung away for ready access to main-frame components

Mark 3 Multelec *recorder*

—uses the same system and components as those in the electronic circular-chart recorder in the KENT *Commander* range. It retains, however, the same easy-to-read strip-chart (10 in. width) used in the *Mark* 2 *Multelec* instrument. The *Mark* 3 is available for the measurement of such variables as temperature, oxygen percentage, millivoltage, reactor power level, and—for certain applications—*Mark* 30 automatic control is included.

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Book Reviews (continued)

various synthetic processes. These serve a very useful purpose in collecting together a great deal of the "know-how" relating to high-pressure technique.

G. F. LAKE

Progress in Vacuum Science and Technology
Edited by A. S. D. Barrett,
Pergamon Press, London, 1959, 160 pp., 70s.

THIS book is interesting but difficult to classify. It consists of a re-issue of the papers contained in Volume 6 of the journal *Vacuum*, bound between stiff covers. The contents include a total of eight papers, and deal with such diverse aspects of vacuum practice as educational facilities, the manufacture of electronic valves, gettering techniques, vacuum metallurgy, vacuum fumigation, vacuum drying, and the process of molecular distillation. The articles are, in general, concerned more with descriptions of the appropriate apparatus and techniques than with a critical examination of the theoretical background. Assessment of the book would have been helped by a prefatory note explaining why these particular articles had been chosen as representative of the title of the book, and also by an indication of the class of reader for which the book is intended.

Considering the contents in greater detail, particulars are given by J. Yarwood of the facilities available for education in vacuum technology at universities and technical colleges in the United Kingdom. Yarwood suggests that more time should be spent in experimental work on vacuum apparatus, and less time devoted to information that can be obtained from manufacturers' catalogues. One might point out here that, although the principles that govern molecular motions are basically the same for all applications of vacuum technique, the essential differences in practice, for example between equipment that is used for exhausting electronic apparatus and that used for pumping condensable vapours, do not always receive sufficient recognition.

Some vacuum problems of the electronic valve industry are discussed by Dr. N. W. Robinson, the gettering process being examined by Dr. della Porta. In both these articles particulars are given of various theories of operation and of typical applications. The processes of vacuum treatment of metals by induction melting and by consumable-electrode melting are described by A. E. Franks; one of the illustrations showing a 3000-lb. induction vacuum furnace.

Applications of vacuum fumigation and vacuum drying are surveyed by W. Burns Brown and the late Dr. E. W. Flosdorf respectively, these two articles being mainly descriptive and illustrated by representative examples of items of equipment and installations. A comprehensive review of the molecular distillation process is provided by P. R. Watt, the bibliography to this paper containing 176 references. The author adopts a practical approach to a wide range of applications, many designs of different types of molecular stills being depicted and their special features discussed. This is one of the best practical articles on the subject ever published.

In brief, the book under review contains much useful information, but the papers appear to have been selected more for their general interest than as a means for providing the specialist with new or original information relating to his particular field.

G. BURROWS

Nuclear Reactor Materials
by B. R. T. Frost and M. B. Waldron
Temple Press, London, 1959, 80 pp., 12s 6d.

THIS monograph is a recent addition to the excellent series issued by *Nuclear Engineering* in which the subject-matter is treated broadly enough to be of value to the general reader while, at the same time, sufficiently up to date to be of interest to the specialist. It is based upon lectures given on the materials of construction for nuclear reactors by the staff of A.E.R.E. at Queen Mary College. The six chapters include sections on theoretical metallurgy, structural and fuel materials, liquid metals, ceramic fuels and corrosion problems.

The chapter on structural materials is devoted almost entirely to those which have either been employed or considered as suitable fuel element canning materials. The use of aluminium, beryllium and the magnesium alloys is examined in some detail. A notable omission is stainless steel which, if the sheath is thin enough, is considered by some to be sufficiently robust in service to justify the higher parasitic absorption of thermal neutrons. Plant constructional materials are hardly touched on except for a brief reference to the problem of brittle-ductile fracture in pressure vessel steels. This is an important omission, since many reactors, for example the fast reactor and pressurised water reactors, have a capital cost which could be improved if cheaper alloy steels are substituted for stainless. In this respect some discussion of clad steels might be relevant. These omissions, however, do not detract from the overall merit of the book. The authors have had a difficult task in condensing the metallurgical development over the last decade in what is generally acknowledged to be the most rapidly developing field of technology.

The chapter on liquid metals and ceramics makes interesting reading and gives a balanced and up-to-date review. Sodium, bismuth and fused salt technology are discussed and the key problems of contamination and mass transfer are adequately dealt with.

The extensive bibliography could be improved by references to the many important papers on the subject which have now been declassified and are available through H.M.S.O.

B. E. ELTHAM

SHORTER NOTICES

Pharmaceutical Legislation in Great Britain, by Allan Duckworth. The Association of British Pharmaceutical Industry.

Mr. Duckworth is the Secretary of The Association of British Pharmaceutical Industry and the brochure is a reprint of a paper presented at the International Congress on the Problems of European Pharmaceutical Legislation held under the auspices of the Italian Society of Pharmaceutical Science, Rome, May 1959.

References to Scientific Literature on Fire, Part IX, 1955, by Miss E. M. Shakeshaft and Mrs. B. F. W. Rogowski. Fire Research Station, Boreham Wood, Herts.

This is part of a continuing project for publishing lists of references to the literature on fire year by year. References are classified under the headings Occurrence of Fire, Fire Hazards, Initiation and Development of Combustion. Fire Precautions, Fire-resistance, Fire-fighting, Atomic Energy and General. There is a name index and a subject index.

Survey of Solubility Diagrams for Ternary and Quaternary Liquid Systems. D. M. Himmelblau, B. L. Brady and J. J. McKetta, Jr. University of Texas, 1959, 42 pp., $2.

The authors, members of the chemical engineering department, University of Texas, have made a thorough literature survey on all of the water and organic liquid systems which have been published prior to June, 1958. References to the following groupings are presented:

Group 1. Systems containing water and two organic compounds with a cross-reference between the most common systems.
Group 2. Non-aqueous organic systems with cross-references.
Group 3. Systems containing liquid propane and two non-aqueous components.
Group 4. Quaternary systems.
Group 5. Systems containing water, one organic liquid and one metallic-organic compounds.

An Introduction to the Study of Chemical Thermodynamics, by D. H. Everett. Longmans, Green & Co., London, 1959, 240 pp., 28s.

The primary object of this book is to acquaint the student meeting thermodynamics for the first time with the basic ideas upon which the applications of thermodynamics to chemistry are founded. It may also assist those chemists who have already studied thermodynamics to achieve a clearer appreciation of its value to them. The author adopts the view that a student should appreciate how thermodynamics can be of value to him before he is required to apply himself to a rigorous study of the formal principles of the subject. To achieve this object, mechanical analogies are used to justify the introduction of concepts which cannot be defined rigorously without the use of strict thermodynamic arguments.

SM/B 4957

During wartime, gas masks were issued for filtering out poisonous and harmful constituents from air in the event of a gas attack. Birlec adsorption dryers are used for removing water vapour from process gases employed in modern manufacturing techniques. For process protection in the metallurgical, chemical and electrical industries, dew-points below —40°C. are frequently required. Standard Birlec dryers are available for such applications and specialised equipment can be built for obtaining dewpoints down to —100°C. Users of one or more of the gases listed alongside are invited to write to Birlec for a copy of Publication No. 82/4.

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PLANT EQUIPMENT NEWS

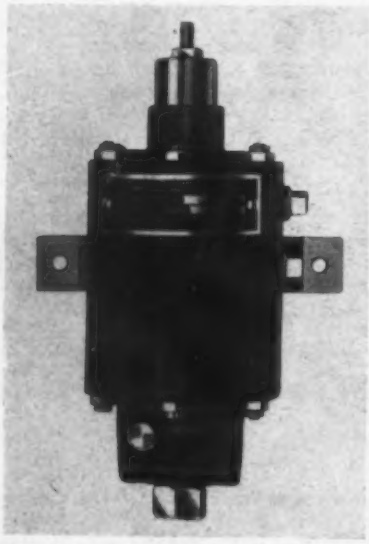
Multi-wash System for Dust Collection

Efficiency of the order of 99% for all particles above 3-4 microns is claimed for a multi-wash system for particles giving lower pressure drop than many other types of wet washer and an absence of circuit restrictions which might cause blockages. The system is based on using centrifugal forces in the cyclones in the lower portion of the collector to throw out the heavier particles, combined with bombardment of the dust particles by a finely divided self-induced spray, and contact between dust-laden air and wetted plates having a large total surface area. Each multi-wash collector consists of a variable number of impingement or washing stages depending on the efficiency required. Each impingement stage consists of a number of mild-steel turbine-like blades welded to a shallow cone. These impingement stages are arranged within the collector, the lower portion of which is formed into a conical hopper to drain off the mixture of water and dust. A standard multi-wash system consists of a multi-wash collector, fractionating or compensating exhaust hoods, velocitraps for removing heavier particles and various types of dewatering tank. This Holmes-Schneible system was shown at the recent Clean Air Convention. **W. C. Holmes & Co. Ltd., Turnbridge, Huddersfield.**

BCE 6942 for further information

Differential Pressure Transmitter

A new product by Taylor Controls Ltd. is a mercury-less force balance differential pressure transmitter, which is 6½ in. long by 3 in. diam., and only weighs 4½ lb. It is a simple instrument for the measurement of flow, liquid level, pressure or density of fluids. The operation is pneumatic, a 3 to 15 psi signal being transmitted with an accuracy of 1%, covering ranges 0 to 50, 100, 200 and 300 in. of water. Some of the outstanding features of the transmitter are: simplified piping, because it can be close-coupled to orifice flanges; no seal pots required. Negligible displacement because of force balance construction; external zero and range adjustments; self-draining or venting—no periodic manual venting or draining; overrange to full working pressure (150 psi) with no permanent damage; compact, weather-proof. Built for rough service and outdoor mounting.



During operation, the measured fluid received in the process side of the transmitter exerts a force on the sensing diaphragm proportional to the differential pressure. This force moves the stack, establishing the distance between baffle and nozzle. The baffle-nozzle relation determines the transmitter output air pressure which is also the feedback pressure against the stack. With an increase in differential pressure, the baffle approaches the nozzle. The resulting increase in output air and feedback pressure forces the stack back to its approximate original position. **Taylor Controls Ltd., 75 Hale End Road, Walthamstow, London, E.17.**

BCE 6943 for further information

Frequency Meter

A new instrument of wide utility, the frequency meter Type 265, has recently been announced by Airmec Ltd. This instrument will measure the frequency of a repetitive waveform in the range 10 c/s to 100 kc/s to an accuracy of ±1%. The input waveform is squared and limited, and applied to an integrating circuit, the voltage across which is indicated on a large, clear, panel meter. The circuitry is so arranged that the meter reading is independent of the amplitude or waveform of the input voltage.

Industrial users will be interested in the application of the instrument as an electronic tachometer. The speed of a rotating shaft may be measured directly by arranging that the shaft makes or breaks a contact at each revolution and applying a voltage, thus interrupted, to the frequency meter. Alternatively, by employing the Airmec optical probe Type 283 in conjunction with the frequency meter, detection of movement is carried out by reflection or interruption of a light beam, and speed measurements may be obtained without loading the equipment under test in any way. The frequency meter is fully transistorised, light and portable, and may be powered from a.c. mains or the internal batteries. Power supply and signal connection for the optical probe are available at a rear socket. An internal calibration check is provided by means of a stable 5 kc/s oscillator, and the meter is calibrated directly in frequency and rpm. An external meter or recorder may be fed from a socket on the front panel. Full details from **Airmec Ltd., High Wycombe, Bucks.**

BCE 6944 for further information

Nylon Tubing

Advantages of nylon "H" tubing include a wide temperature range (−74° to 105°C), absence of plasticiser, high resistance to vibration, crushing, abrasion impact and resistance to corrosion. The tube is unaffected by oils, hydraulic fluids, alkalis and most solvents, resistant to rats and stores indefinitely. It can be rapidly installed in awkward and inaccessible positions, and will withstand pressures of up to 2500 psi. It can be supplied in five sizes, with outside diameters from 0.125 in. to 0.375 in. and inside diameters from 0.078 in. to 0.225 in. respectively. **C. C. Wakefield & Co. Ltd., 46 Grosvenor Street, London, W.1.**

BCE 6945 for further information

Unit Sequencing Controller

Automatic sequential control from a central position is rendered possible by the use of a unit sequencing system which is cheaper than the use of full automation. The controller implements instructions automatically in accordance with a predetermined programme of operations. It is actuated by means of electrical signals received on completion of each stage of a production process. This may be a pre-set time, temperature, pressure, weight, number of revolutions, power, density or other property. The system then controls operations such as mixing, heating, cooling, pumping, conveying and so on. Standard units may be built up as required to meet individual requirements. **Gresham Developments Ltd., Thirlestane House, Uxbridge Road, Hampton Hill, Middlesex.**

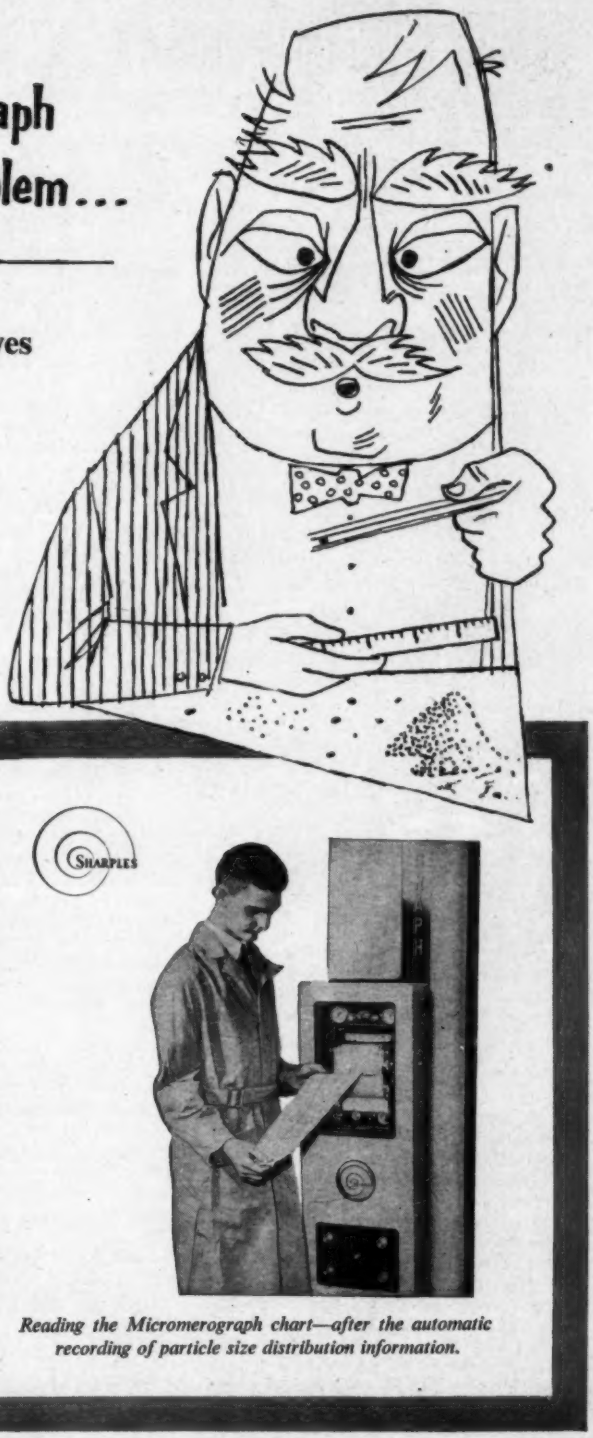
BCE 6946 for further information

Non-spill Pipe Coupling

Faced with the necessity of reducing to an absolute minimum spillage of radioactive liquids and with the fact that designs of "self-sealing" couplings currently on the market do not give the degree of fluid-tightness required in nuclear energy work in the course of making or breaking a joint, an engineer of the United Kingdom Atomic Energy Authority's Harwell Research Establishment has invented his own design.

The coupling is extremely neat and simple and contains a minimum of moving parts. In the disconnected state, i.e., with both ends sealed off, the valve which closes the delivery side—subjected to the higher pressure—is held tightly shut against a sealing ring by the action of a flexible metal bellows to one end of which the valve is welded. These bellows are held under constant pressure by the liquid in the pipeline and,

We designed the micromerograph to solve our own particle problem...



Reading the Micromerograph chart—after the automatic recording of particle size distribution information.

. . . but it was too good to keep to ourselves

When you're dealing with separation problems every day it's essential to be able to measure accurately the size of very small particles.

All the existing methods had their snags. So we set about developing our own instrument. And over the years we developed the Micromerograph. It was so highly successful that we felt we ought to manufacture it and offer it to others who need a rapid, accurate, reproducible means of particle size analysis. It is now in use in a wide variety of industries.

The Micromerograph uses the air sedimentation technique which can be operated with solids in low concentration, due to the simultaneous development of a high precision null-deflection balance. The built-in deagglomerator applies a controlled and reproducible shear force to the powder sample so that particle aggregates can be broken down, whilst causing no destruction of individual particles. An automatic recorder gives a continuous statement of data.

The whole instrument is robust and automatically operated. Relatively unskilled personnel can use it. The Micromerograph has put into the hands of industry a means of production control and research which was previously unobtainable. Already many users have obtained dramatic improvements of product quality due to their use of the Micromerograph.

Another example of particle handling by Sharples is the new Sharples Super Classifier—a unique air vortex classifier that combines an ultra-sharp cutpoint with high capacity and unmatched efficiency. Write for Bulletin 1280 describing the Super Classifier.

Write for Bulletin No. 456M describing the Sharples Micromerograph or, if you wish, phone Camberley 2601 and talk to Martin Trowbridge about your problem.

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their other end being attached inside the pipe, only that end which carries the valve can move, sliding the valve up and down a sleeve. The receiving side of the coupling is closed off by a piston valve which is held shut against a sealing ring by a compression spring. A screw-threaded connector is used to link the two sides of the coupling, and when it begins to draw them together a protruding metal ring on the outer body of the receiving side immediately presses against a sealing ring on the outer face of the sliding valve in the delivery head, providing a liquid-tight seal. As the connector continues to tighten, this sliding valve is pushed back while a protuberant disc on the face of the sliding valve forces back the receiving piston valve from its seal. When the delivery valve has moved back a little on its sleeve, it begins to uncover a number of holes in the latter to give passage to the liquid in the pipeline. This can then flow through the coupling and around the piston valve into the receiving head. In the reverse direction, as the coupling is unscrewed, delivery apertures and piston valve close before the seal between the two sections is broken. A very important feature of the geometry of the internal passages of the design is that when the coupling is being unscrewed, these passages close completely and thus cease to hold any liquid, before the two sides are released. Therefore, the only liquid remaining in the system will be the very small amount wetting the exposed surfaces. The U.K.A.E.A. has granted a licence to the Seaton Creaghe Engineering Co. Further information is available from the **Patents Exploitation Officer, United Kingdom Atomic Energy Authority, 11 Charles II Street, London, S.W.1.**

BCE 6947 for further information

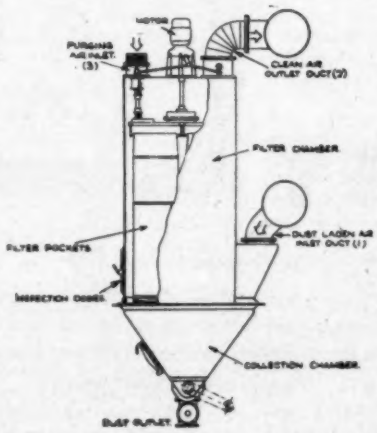
"Hi-Grad" Conveyor

A new design for the elevating of granular materials by belt conveyor in restricted locations has recently been introduced by Birtley Engineering Ltd. This design, the Birtley "Hi-Grad" conveyor, can operate at angles up to 50 degrees, and thus avoids the need for complicated and expensive conventional conveying layouts. The basic features of the Hi-Grad are a lower, carrying, troughed belt and an upper, retaining, belt, the latter being fitted with transverse flaps. The material being conveyed is constrained between these two belts, a common drive being employed for both. Feed on to the conveyor is by means of a rotating transfer drum fitted with an automatic material flow control, which ensures a delivery from the feed hopper to the carrying belt only when the conveyor is running. A typical application of the Hi-Grad is shown illustrated. In this the conveyor is elevating 250 tons an hour of sand or variously graded aggregate at an angle of 35 degrees from a ship discharge point to a mixing plant. The conveyor will handle effectively finely powdered materials, grains and lumpy materials and, in cases where there is a tendency to adhere to the conveying surfaces, the carrying belt can be cleaned by means of a conventional scraper at the head end. High capacities are said to be achieved and power consumption and maintenance at a minimum when compared with other methods of steep angle elevating. The use of special belts is avoided and, consequently, there is said to be no problem of spares replacement anywhere in the world. **Birtley Engineering Ltd., Birtley, County Durham.**

BCE 6948 for further information

Automatic Dust Filter

In collaboration with the German company of Otto Hubbe, Keith Blackman Ltd. are now manufacturing under an exclusive licence arrangement the well-established Fischer automatic dust filter (Pat. Nos. 752,138, 752,693, 758,207 and 773,738). This filter is available in two basic types, one of square section containing 24 rectangular filter "pockets" and the other of circular section containing 27 circular filter sleeves. In operation the dust-laden air enters at (1) as shown in the diagram of the square section filter and passes down into the collection hopper, where the heavy particles are settled out. The air then passes through the fabric filter pockets in the filter chamber, where the remaining dust is trapped while the clean air passes out at the clean air outlet (2) and into the main extraction duct leading to the fan, the filter chamber always operating under suction. Two or more filters are installed adjacent to one another, the number depending on the volume of air and dust passing into the filters. At predetermined intervals which depend on the conditions under which the plant is operating, a motor-operated damper in one of the filters causes the dust-laden air to by-pass the filter which then undergoes its cleaning cycle. This same motor simultaneously opens another damper and air is drawn through the purging air inlet (3) into the filter chamber, passes through the pockets in the reverse direction (from outside to inside) carrying the collected dust into the main dust collection hopper where most is deposited. The purging air then passes through (1) into the inlet duct to be mixed with the dust-laden air which is being directed to the adjacent filters which are meanwhile in normal operation. **Keith Blackman Ltd., Mill Mead Road, London, N.17.**



BCE 6949 for further information

Special Steels

At the Scottish Industries Exhibition Colvilles were showing clad steels developed from laboratory tests in which two plates of stainless steel, each 3 ft × 3 ft × ¼ in., were coated on one surface with a layer of mild steel deposited manually by the electric arc process. They were then placed with the stainless-steel surfaces in juxtaposition with a parting compound between them. This inner sandwich was then placed inside two larger and thicker mild-steel plates and the whole welded into a pack. This pack or composite was then heated and rolled in a conventional plate mill. After rolling, the pack was cooled and cut round the edges of the inner stainless-steel plates. From this pack, two plates were produced, each of which consisted of a mild-steel plate, clad on one surface with a layer of stainless steel. Microscopic examination showed that a continuous joint had been obtained. Tensile tests on the plates showed that the material behaved as a homogeneous plate. Bend tests with the cladding in tension and compression did not show any sign of separation. This operation has now been successfully adapted to large-scale production using chromium oxide as the separating compound. The clad steels are commercially available. **Colvilles Ltd., West George Street, Glasgow, C.2.**

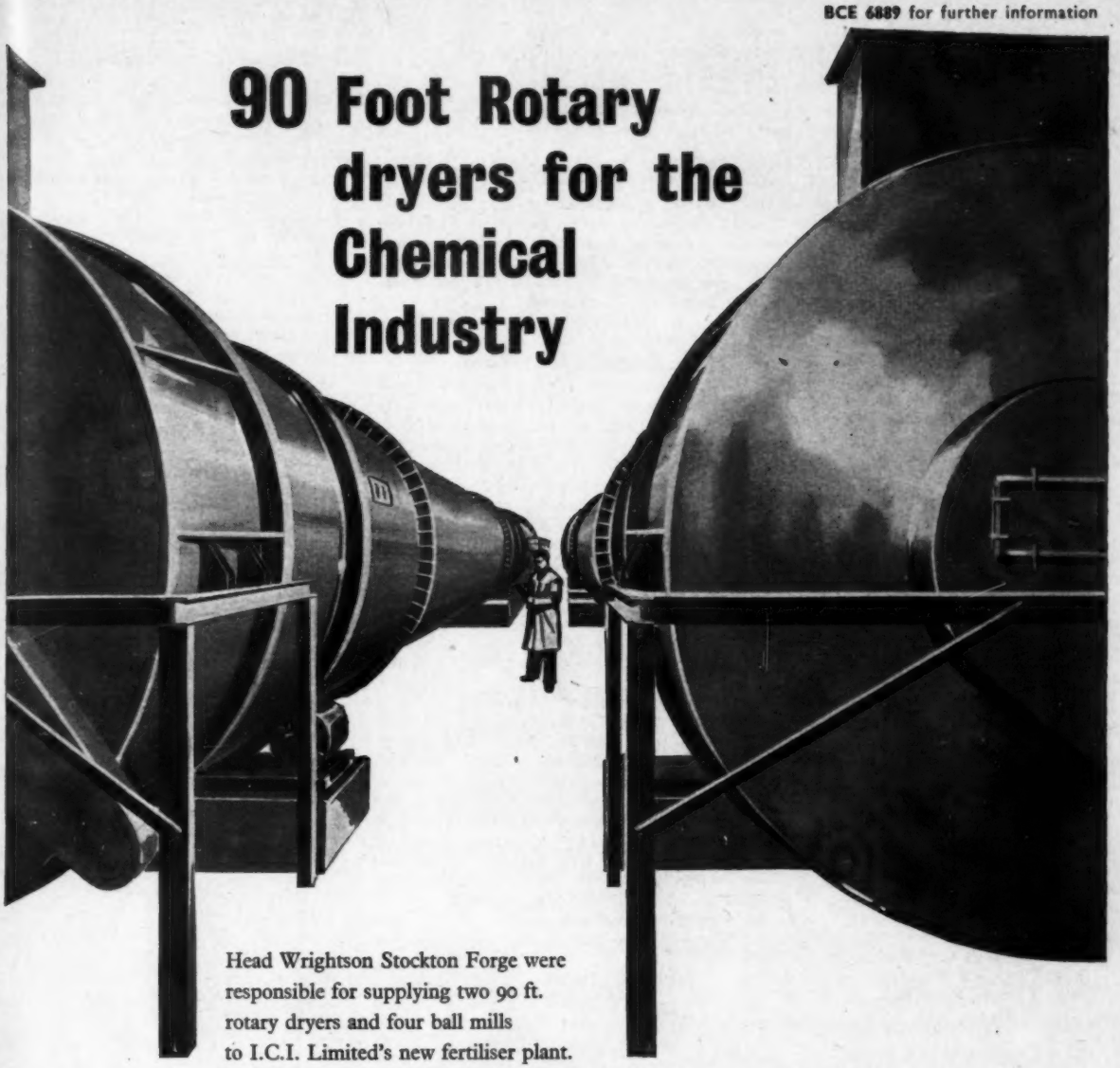
BCE 6950 for further information

Coupling for Glass Pipes

Serpentine coolers of borosilicate glass have been successfully used for cooling sulphuric acid in all concentrations and temperatures. The glass is also resistant to mixtures of sulphuric acid with oxides of nitrogen. Joints had, however, previously offered some difficulties, due mainly to the effects of differential thermal expansion and the high density of the acid. QVF Ltd. state that they have successfully overcome this problem by using an entirely new type of pipe coupling, invented and developed by Scottish Agricultural Industries Ltd. It consists of a moulded rubber sleeve designed to fit over the tapered buttress ends of glass pipe sections and bends. The

BCE 6889 for further information

90 Foot Rotary dryers for the Chemical Industry



Head Wrightson Stockton Forge were responsible for supplying two 90 ft. rotary dryers and four ball mills to I.C.I. Limited's new fertiliser plant. The dryers are among the largest machines of this type ever to be built.

Head Wrightson have specialised in the design and manufacture of drying and grinding equipment for the Chemical and Mining industries for many years and have installed similar equipment in many plants in this country and abroad.

Please write for further information or telephone Stockton 65268.

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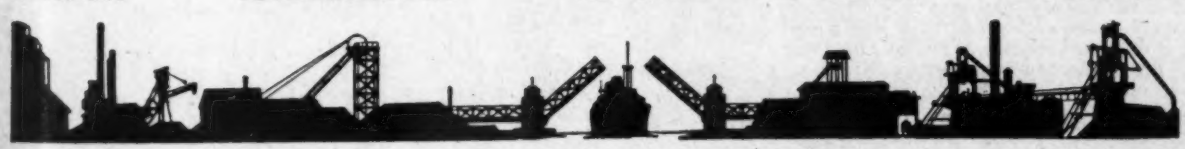


P.3732

PLANT EQUIPMENT NEWS

sleeve is backed by a stainless-steel gaiter having lugs formed on its edges, some facing outwards and some inwards. The gaiter is secured by two worm-drive clips which are prevented from moving down the taper by the outward-turned lugs, and the rubber sleeve is retained under the gaiter by the inward-facing lugs. The bore of the sleeve has a corrosion-resisting insert which forms a seal around the periphery of the pipe ends. The new joint is more compact than the standard flange. Patents have been applied for. **QVF Ltd., Duke Street, Fenton, Stoke-on-Trent.**

BCE 6951 for further information

Continuous Flow Differential Refractometer

For the continuous monitoring of quality by measurement of refractive index, a flow type of refractometer may be applied. One model available makes a continuous comparison between the property in a reference liquid and that of the flowing sample. Any change in the concentration of the sample is shown on a meter or recorded. The instrument can be incorporated in an automatic system to apply control or corrective action. It has many applications in the brewing, chemical, sugar and pharmaceutical industries.

A null-balance system of measurement is employed and any change in the refractive index of the sample unbalances the system. A simple servo mechanism restores the balance and indicates the difference between the indices of the sample and reference liquids. The cells are maintained at a constant temperature by a water jacket. **Hilger & Watts Ltd., 98 St. Pancras Way, Camden Road, London, N.W.1.**

BCE 6952 for further information

P.V.C. Fitting

A method of overcoming the expansion problem encountered when plastic pipe installations are subjected to temperature variations has been developed by Barflo Ltd. by the introduction of a device known as the Barflo expansion unit. The male end of the unit passes through an O-ring; this forms the main seal and allows telescopic action of the components contained in the cylinder. Auxiliary packing glands at each end of the cylinder enable repacking to be carried out, thereby prolonging the working life of the unit. The pipeline need not be interrupted when renewing the packing. Expansion can be controlled over a movement of 2-12 in. according to the size of the unit employed. Installed pipe runs of sizes from ¾-6 in. i.d. are possible. Special units can be constructed in sizes beyond the standard range in order to meet special requirements. The expansion units are constructed from P.V.C. piping made by Durapipe & Fittings Ltd., Winnock Road, West Drayton, Middlesex, using Geon RA.170 High Impact P.V.C. which is made by British Geon Ltd.

Plastic wedge gate-type valves with a free flow in pipe sizes (British Standard Specifications) from 1 to 3 in. (larger sizes are being developed) are also being manufactured by Barflo Ltd. The valve can be supplied in several types of known rigid plastic materials and with optional flanged or screwed fixings. **Barflo Ltd., 56 Cavendish Place, Eastbourne.**

BCE 6953 for further information

Safe Lifting Clamp

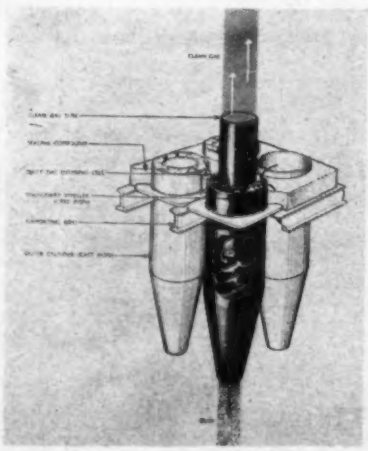
Interlas plate lifting clamps are now available in the United Kingdom in seven different sizes to accommodate loads of 1½ tons max. to 20 tons max., and plate thicknesses of ¼ in. max. to 3 in. max. Interlas clamps are designed to lift plates or fabricated plate sections without any danger of the load slipping. The greater the pull, the tighter the cam-operated jaws grip the plate, and even when the weight of the plate is taken on the ground, the clamp cannot loosen until the locking lever has been released. When the clamp has been released, it can be pulled away easily, as there are rollers which run on the plate.

Such is the grip of the clamp that a plate can be raised from horizontal to vertical or lowered from vertical to horizontal in complete safety. Interlas N.V. of Holland were the originators of the double-cam-operated lifting clamp, and they have supplied thousands of them to shipbuilding and general engineering firms on the Continent. Now the full range is available from the British Associates, **Interlas Ltd., 9 Church Street, Ampthill, Bedford.**

BCE 6954 for further information

Multi-Cell Cyclone Dust Collector

A recent addition to the range of dust collection and control plant manufactured by the Gas Cleaning Division of W. C. Holmes & Co. Ltd. is the type "UK" reverse flow Holmes-Rothemuhle multi-cell cyclone dust collector. This collector has a higher collection efficiency than the type "RM" through-pass collector which was introduced into the United Kingdom in 1957, and is particularly suitable for those applications where good gas distribution conditions cannot economically be achieved and where large gas volumes are encountered. The collector comprises an assembly of cyclone cells, the number of which is directly proportional to the volume of gas to be cleaned. Each cyclone cell consists of two concentric tubes: an outer dirty-gas cylinder with a stationary impeller fixed at the inlet and an inner clean-gas tube which passes up through the centre of the impeller. The outer cylinder is approximately 10 in. in diam. except at the base, which is conical in shape. The high separating efficiency of the collector is derived from the relatively small diameter of the individual cyclone cells. In operation, the impeller imparts an intense swirl to the dust-laden gas as it enters the cell, causing it to descend with a spiral motion. Near the apex of the conical section of the dirty-gas cylinder the axial velocity of the spiralling gas is turned through 180 degrees. The dust-free gas, having reversed direction, passes up through the clean-gas tube to the exhaust fan and stack. The reversal of direction of flow causes the dust to be centrifuged and it is propelled downwards into the dust bunker. **W. C. Holmes & Co. Ltd., P.O Box B7, Turnbridge, Huddersfield, England.**

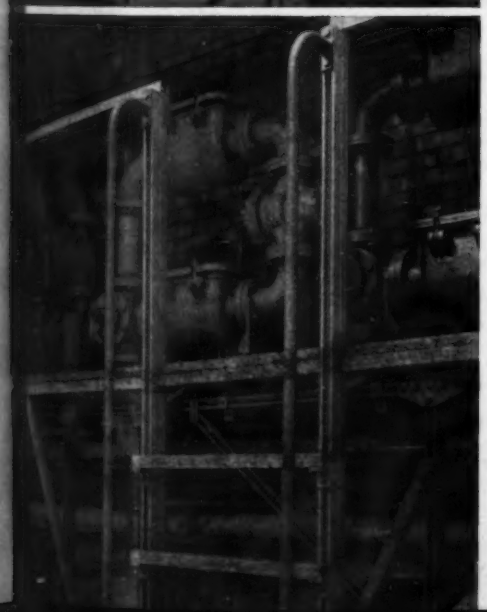


BCE 6955 for further information

Transistorised Temperature Controller

The first of the new Feilden "Bikini" range of transistorised instruments has just been released. This is a precision temperature controller with a differential of only 0.5°C, high calibration accuracy and very high long-term stability. The instrument is housed in a small meter-type case and occupies a panel space of only 4½ in. diam. The scale, which is 9 in. long, is calibrated directly in °C or °F and the bold pointer is set to the required control temperature by a small knob in the centre of the instrument. A red lamp visible from the sides as well as from the front indicates the control action. The meter-type case is completely sealed and contains no galvos, pivots or other delicate moving parts and the instrument can be mounted at any angle; for example, on a sloping control desk. Control can be at any temperature between −200°C and +500°C with a minimum temperature range span of 50°C and there are 12 standard calibrations in °C and °F.

BCE 6890 for further information



more UNISTRUT in Chemical Engineering

Rigid support—flexible solution to layout problems

Confronted by the twin problem of installation cost versus future maintenance or plant alteration, forward-looking Chemical Engineers are standardising more and more on Unistrut to support and locate service pipes, flow lines, process control equipment, and instrumentation. Some typical applications are shown on this page.

Unistrut cuts installation costs

This versatile support system, based on a compact yet rigid cold-rolled steel channel section and self-locating nut assembly, eliminates prefabrication or support structures, which can now be made up (and if required adjusted) entirely on site. The rapid assembly method and the design of the comprehensive range of fittings radically reduce time and labour requirements, materially assisting speedy completion and low installation cost.

Maintenance, changing needs, temporary installations

While capable of sustaining heavy loads and stresses (such as those set up by pipe creep), Unistrut also permits fine adjustment in the location of fittings to support delicate equipment, glass vessels and pipes. Structures can be added to or adjusted at any time, and maintenance work is simplified. This has also led to the use of Unistrut for pilot plant and experimental rigs, all components being re-usable.

Further information

For information on Unistrut in pipe-running, electrical trunking, racking and other support applications, please write to the address below.

Unistrut is used by:—
CALTEX LTD · ESSO PETROLEUM CO. LTD · VITAMINS LTD
GLAXO LABORATORIES LTD · MONSANTO CHEMICALS LTD
IMPERIAL CHEMICAL INDUSTRIES LTD · PETROCHEMICALS LTD · ROCHE PRODUCTS LTD · SHELL-MEX & B.P. LTD

UNISTRUT

STEEL CHANNEL FRAMING SYSTEM

Unistrut Division of Sankey-Sheldon Ltd.
A member of the Guest, Keen & Nettlefolds Group of Companies.
43-45 Broadwater Road, Welwyn Garden City, Herts.
Telephone: Welwyn Garden City 6321 (4 lines).

PLANT EQUIPMENT NEWS

A platinum resistance element is used at the temperature measuring point, this being housed in a robust, stainless-steel sheath of ¼ in. diam. Ordinary connecting cable is used between the measuring point and the instrument and this can be up to 300 ft in length without introducing errors.

The control action is on/off, either electrical or pneumatic. The electrical contacts give changeover switching at 5 amperes 250 volts, whilst the pneumatic valve requires 17 to 20 psi input. Inexpensive power supply units are available to provide the necessary 12 volts d.c. from the usual supply mains. These can be supplied for one or a number of instruments and can be fitted with or without the electrical control relays. **Fielden Electronics Ltd., Paston Road, Wythenshawe, Manchester, 22.**

BCE 6956 for further information

Alloy Plug Valves

Plug valves have many desirable qualities, but the classic design has the undesirable feature of the possibility of sticking. This has been overcome in a number of designs by the use of lubricants, but this introduces other factors which may prove undesirable. The presence of lubricant in the pipeline contaminating the product may not be acceptable and regular attention to lubrication is necessary to ensure that a valve can be operated with certainty when needed. All the advantages of the plug valve are available in the Langalloy-Durco type "F" plug valve and the disadvantages are said to have been eliminated by the use of a sleeve of P.T.F.E. between the body and the plug. This design was developed by The Duriron Co. Inc., of Dayton, Ohio, U.S.A., and has been proved in countless applications in America. By agreement, the identical design is now produced in the U.K. by Langley Alloys Ltd. and these valves are available in stainless steels, nickel alloys and all the other alloys in which the standard Langley valves are already produced. The main advantages of the design are elimination of metal-to-metal contact, elimination of need for regular attention on site, no lubricant costs, no contamination of the product, ease of operation, extreme ease of maintenance—a new sleeve can be fitted in a matter of minutes. At the same time all the obvious good features of the plug valve are retained. **Langley Alloys Ltd., Langley, Slough, Bucks.**

BCE 6957 for further information

Vibratory Conveyor

A new type of vibratory conveyor has been developed by Sinex Engineering Co. Ltd. Known as the Sinex vibratory conveyor, it is said to have all the advantages of the magnetic conveyor (except that it has a fixed rate of feed), i.e., few moving parts, low maintenance requirements and silence of operation. It is particularly adaptable where very little headroom is available. Applications for which it is specially suited are those involving the simple transfer of material from one point to another; the feed can be stopped or started at will and although the speed of travel remains constant the level of material can be altered by means of a gate to control the amount being fed. The vibratory conveyor, the length of which is adapted to suit requirements, comprises a feed trough fitted with a pair of the new standard SV range of Sinex electric vibrators, one on each side of the trough. The vibrators are mounted with their shafts in a vertical plane, but inclined at a specific angle to provide a feed of material in one direction along the trough. Each conveyor can be supplied complete with base structure or with simple mountings for attachment to the customer's own equipment. The only moving parts employed are the rotors of the vibrators. Vibrators can be quickly replaced if this eventually becomes necessary, by virtue of their four-bolt lug mountings. **Sinex Engineering Co. Ltd., North Feltham Trading Estate, Feltham, Middlesex.**

BCE 6958 for further information

Hi-Flex Extensible Hydraulic Link

This device has been originally designed and developed by the Oil Feed Engineering Co. Ltd. (High-pressure Hose Division—BTR Industries Ltd.) to be used in connection with their "Hi-Flex" flexible pressure pipes. It answers the direct need for large equipment to be articulated or flexed without the disadvantages of looped hoses which might catch on obstructions.

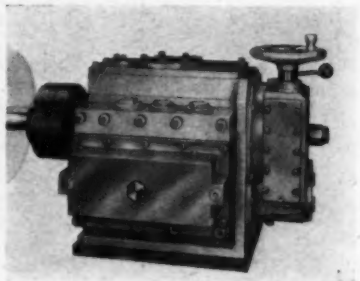
It consists of a tubular member capable of being expanded and contracted axially, and employs a hydraulically-balanced mechanism which enables these movements to be carried out whilst fluid at high pressure is going through the appliance. The resistance to movement is low, so that little energy is absorbed when relative movement takes place between the end attachments.

It has plain tube ends, but could easily be produced with standard male or union ends. The standard model is adapted for ¾-in. feed lines. Its overall length extended is 18½ in. and fully retracted 15 in., but this travel can be extended for special services. The designed maximum working pressure is 3000 psi. The unit is leak-proof and will function for extended periods before replacement of seals is required. Made in mild steel and plated, the component is so designed that seals and moving parts may be easily inspected and replaced as desired. **Oil Feed Engineering Co. Ltd. High-pressure Hose Division—BTR Industries Ltd., Vincent House, Vincent Square, London, S.W.1.**

BCE 6959 for further information

Variable Flow Pump

Sutcliffe Hydraulics Ltd. have introduced a new hydraulic variable flow pump. It is of the multi-piston type operated by camshafts which run in roller bearings. The delivery and suction valves are mitre seated and the basis of the design is simple unit construction together with strength of components to give hard, continuous service. Pairs of pistons operate with common suction and delivery valves and the relative position of the camshaft driving one piston is altered with regard to the camshaft driving the other piston, so giving an infinitely variable flow from zero to full capacity.



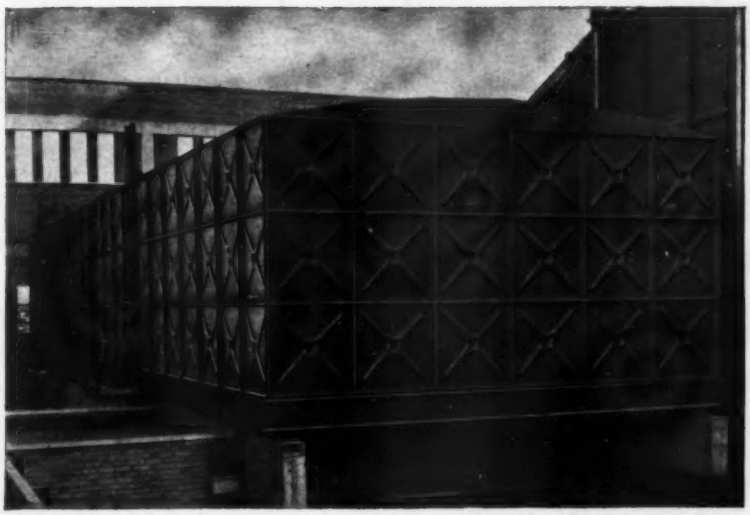
Full pressure is produced down to zero capacity and the pump may be run in either direction to suit the prime mover. The present range of pumps have capacities from 7½ gpm to 50 gpm with pressures up to 2000 psi and various controls such as manual, mechanical, electronic or automatic can be fitted to suit the condition of control required. The pumps can be supplied separately or in the form of power packs. **Sutcliffe Hydraulics Ltd., Speedwell Works, Whitwood, Castleford.**

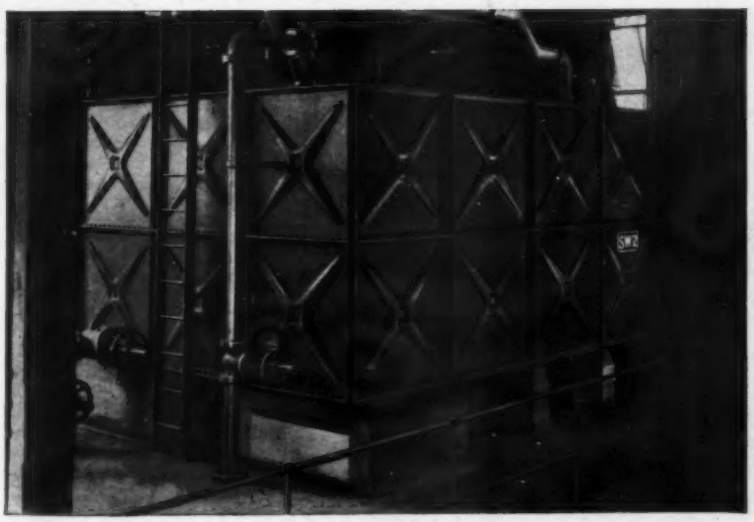
BCE 6960 for further information

Heat-transfer Medium

"Thermex" heat-transfer medium has been added to the range of phenol derivatives made by the Heavy Organic Chemicals Division of I.C.I. "Thermex" (trade-

Braithwaite PRESSED STEEL SECTIONAL TANKS FOR POWER STATIONS





Braithwaite Pressed Steel Tanks with external flanges throughout comply with British Standard 1564: 1949. The sectional method of construction enables tanks with an unlimited range of capacities to be provided. Suitable for the storage of most liquids and viscous substances, they can be economically transported and erected in positions inaccessible to other forms of construction. They can also be increased in size when additional capacity is required. Illustrated brochure will be sent on application.

SELLING AGENTS

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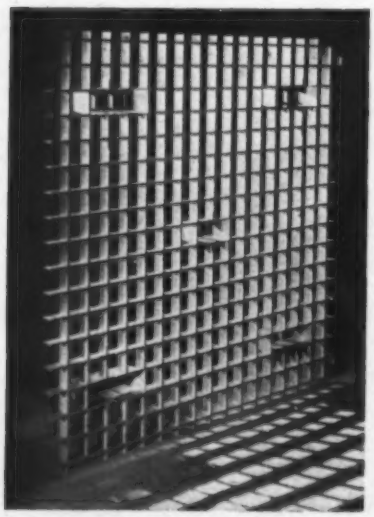
PLANT EQUIPMENT NEWS

mark of Imperial Chemical Industries Ltd.) is a eutectic mixture of diphenyl oxide and diphenyl in the respective proportions by weight of 73.5% and 26.5%. It is the first heat-transfer medium of this type to be manufactured commercially in Britain. A combination of physical properties makes "Thermex" particularly suitable for liquid-phase and vapour-phase heating and cooling in a variety of industrial processes. It has a high boiling point (255°C) and low freezing point (12°C), and excellent thermal stability over long periods at temperatures up to 400°C. It has high heat-transfer coefficients, particularly in the vapour phase; further, it is non-corrosive and presents a negligible fire risk. Typical examples of industrial processes in which "Thermex" can be used are: the melting and spinning of synthetic fibres; the distillation and processing of fats, vegetable oils, petroleum fractions, and other high-boiling products; the concentration of sulphuric acid and caustic soda solutions; the processing of plastics and rubber products by extrusion and moulding techniques; and the manufacture of paints and varnishes. **Imperial Chemical Industries Ltd., Imperial Chemical House, Millbank, London, S.W.1.**

BCE 6961 for further information

Water Cooling Towers

After many years of research and development, Fluor Products Co. in the U.S.A. and Head Wrightson Processes in the United Kingdom have introduced Polygrid plastic packing for water cooling towers. Ekco Plastics of Southend have



carried out the moulding in Britain of these grids. Moulded in high-density polyethylene they are expected to have a considerably longer life than wooden slats and they cut the assembly time of the cooling tower while packing a greater cooling capacity into a given space. They can be interlocked when assembled one above the other or spaced at intervals in the tower depending on the duty required; they measure approximately 3 ft square. For applications in which the water contains no hydrocarbons, high-impact polystyrene may be used in place of polyethylene and the mould has therefore been designed to cater for either material. **Ekco Plastics Ltd., Southend-on-Sea, Essex.**

BCE 6962 for further information

Electric Motor for Vibrating Drives

A new electric motor specially designed for vibrating drives, the first of its type to be made in the United Kingdom, is being produced jointly by The English Electric Co. Ltd. and the Grantham Electrical Engineering Co. Ltd. The completely self-contained unit provides an inexpensive and reliable drive by eliminating all the mechanical parts associated with an eccentric shaft arrangement. Vibration is generated by out-of-balance weights at either end of the motor which can easily be adjusted by single bolts to give the required output.

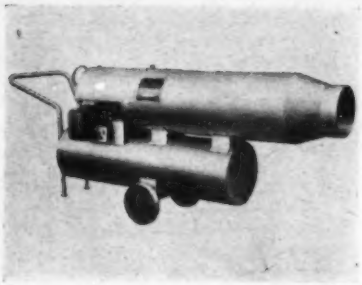
It is of robust construction, having heavy-duty bearings with special features to deal with out-of balance loads. Tests have shown that a bearing life of many thousand hours can be expected, the bearings being lubricated for life.

The motor is totally enclosed, dust-proof and weather-proof and, because of its vibrating motion, must be mounted on a resilient base. Operating at 1500 rpm synchronous speed, it has a power output of up to 7500 lb. centrifugal force, or 10,000 lb. at 3000 rpm, which is ample for all applications at present envisaged. The motor is operated from a 3-phase, 50-cycle supply at 110-650 volts. Greater outputs and other supply frequencies can be provided for. It is built to B.S. 2613, having Class "E" insulation on the windings, which permits a temperature rise of 65°C in a surrounding temperature of 40°C. The new motor is being marketed by both **English Electric, Bradford,** and the **Grantham Electrical Engineering Co, 6 Wharf Road, Grantham, Lincs.**

BCE 6963 for further information

Neo-Jet Heat Unit

The Neo-Jet Heat Unit, completely mobile, is an oil-burning unit which is extremely economical in operation. With simple modifications of the nozzles, it can supply air from 100°C to 300°C in temperature and, with the aid of various attachments, this hot air can be safely directed to a number of purposes requiring the application of controlled heat. The Neo-Jet measures 4 ft overall length and weighing, filled, about 3 cwt. has a capacity of 15 gals. Brief specification: Casing, 12 in. diam. mild-steel construction with conical nozzle; Combustion chamber, heat-resisting steel construction; Burner, pressure jet type; Oil, 35 sec. viscosity (gas oil); Capacity,



¼ to 1 gal. an hour; Ignition, continuous electric spark; Motor, 0.5-hp single-phase 230-volt capacitor; Fan, axial type; Fan delivery, 400 cfm cold air or 800 cfm hot air; Temperature range, up to 300°C (570°F); Oil Tank, cylindrical mild-steel construction; Capacity; 15 gal. and Weight, 120 lb. with empty tank, 250 lb. with full tank. **Modern Furnaces & Stoves Ltd., Booth Street, Handsworth, Birmingham, 21.**

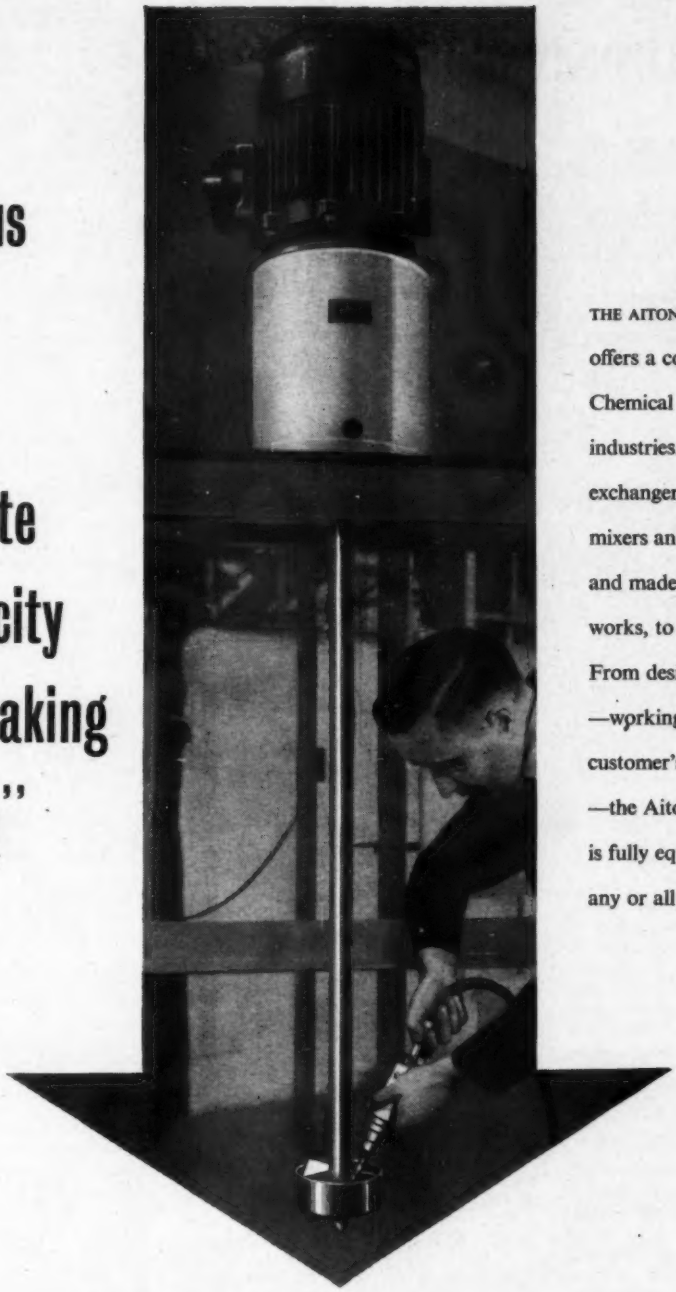
BCE 6964 for further information

Trace Reading Equipment

The TRE12 Trace Reading Equipment is designed for the analysis of physical parameters recorded in analogue form as oscillograph traces. An electric motor provides fast chart drive, either forward or reverse. Control is by push-buttons which actuate magnetic clutches. Manual fine control of the chart position is provided, controlled by a large "thumb-wheel". Non-linear or linear calibrations are equally simple to handle and a single cursor is used for all readings. The record for conversion may contain up to twelve independent channels. In a single scan of the chart all channels may be converted and presented in digital form, each in the actual units of the original parameter. The output may be by electric typewriter, tape perforator or card punch, either singly or simultaneously. Additionally a visual display is included on the cabinet containing the electronic units. Loading the record is extremely simple and may be carried out from the operating position. The complete record feed mechanism is mounted on a rotatable drum for free access. Calibration curves of any type are very easily generated and a separate curve is used for each channel, giving complete flexibility. These curves are produced on graph paper fitted to a drum beneath the trace display window and both curve and record are traversed by a single short cursor. In operating the trace reader and also in the electronic conversion of the readings an accuracy of 0.1% of full scale is easily maintained. Read-out may be controlled by push-button or foot switch. The stepping on to the next channel is automatic and the operative channel is shown on a digital display above the trace window. Where required, a projector attachment is available to allow analysis of traces of 35-mm or 70-mm transparent film.

Ranges are ±999, ±1999, ±4999 with an accuracy of ±0.1% of full scale. Speed of print-out is 1.25 sec.; Scale deflection, full scale output for any trace up to 12 in.

"Genius is the Infinite Capacity for taking pains"



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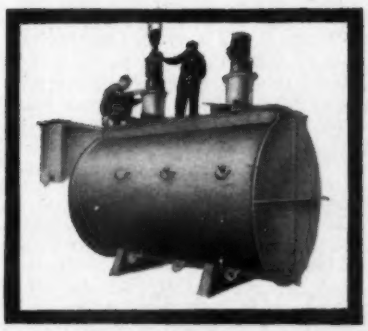

AITON

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PLANT EQUIPMENT NEWS

amplitude. The mains supply is 200-250 V 50 c/s A.C. Consumption 750 watts approx. Dimensions: Trace Reader—26½ × 25 × 16 in. high. Console—Overall base dimensions 2 ft 6 in. square. Overall height 4 ft 10½ in. **Southern Instruments Ltd., Frimley Road, Camberly, Surrey.**

BCE 6965 for further information

Miniature Recording Potentiometer

Two units in identical cases are connected to form a series of miniature potentiometers with recorders. They are a panel-mounted instrument and an amplifier rack mounted separately behind the panel, connected by a multicore cable 6 ft in length to the panel instrument. In the panel-mounted instrument are the chart mechanism and one or two servomotors driving one or two recording pens. In addition, there may be two indicating pneumatic movements or auto/seal/manual switch and air loading regulator to operate with separately mounted pneumatic controller. Another form has a rear-mounted two-term (proportional+integral) stack-diaphragm pneumatic controller, or a three-term (proportional+integral + derivative) stack - diaphragm pneumatic controller. The amplifier contains the electronic amplifier and the constant-voltage unit. The scale of the instrument is 4 in. long and operating speed is 8 sec. full travel standard. Sensitivity is 0.1% of scale span or 0.01 mV for scale spans below 10 mV. Accuracy is ±0.5% of scale span. The use of this instrument means that potentiometric and pneumatic recorders can now be grouped logically on a panel for "miniature presentation" without degrading electrical signals to pneumatic signals before recording. **Electroflo Meters Co. Ltd., Abbey Road, Park Royal, London, N.W.10.**

BCE 6966 for further information

New Publications

The Crane condenser process was developed so that the tubes of conventional straight-tube heat exchangers might be secured and effectively sealed off in their tube plates, while still allowing them freedom to move axially, without deformation or damage to the tube ends. The Crane condenser process is fully described and illustrated in a new 12-page booklet, copies of which can be obtained from **Crane Packing Ltd., Slough, Bucks.**

BCE 6967 for further information

A detailed review has been published by the Gas Council of the furnace plant at Babcock & Wilcox Ltd., makers of steam boiler plant, a member of the English Electric—Babcock & Wilcox—Taylor Woodrow atomic power plant consortium. Accurate heat treatment is essential for almost every item of manufacture and in 1958, 2 million therms of town gas were used in these factories. "Furnace Plant at Babcock & Wilcox Ltd." Report No. 700/59 of the Industrial Gas Development Committee. **Gas Council, Grosvenor Place, London S.W.1.**

BCE 6968 for further information

Last year I.C.I. General Chemicals Division brought into operation a pilot plant on Merseyside for the manufacture of silicon of semi-conductor grade. A larger plant is now nearing completion. The background to semi-conductor devices, their advantages, the use of silicon, its manufacture and properties are given in a booklet, "Silicon for Semiconductor Devices". **I.C.I., Imperial Chemical House, Millbank, London, S.W.1.**

BCE 6969 for further information

Reformulated soluble cutting oils incorporate several improvements which should make these grades more acceptable to users. The new grades contain an improved coupling agent to facilitate the rapid formation of a stable emulsion, and do not now possess the usual odour of disinfectant. This should make them more acceptable, particularly to women operators. In addition, the absence of the conventional phenolic coupling agent reduces the tendency of the emulsion to cause irritation of tender skins. A brochure on these is available from **Shell Mex & B.P. Ltd., Shell Mex House, Strand, London, W.C.2.**

BCE 6970 for further information

A new brochure has been produced by Head Wrightson to show the services offered to the iron and steel industry with special reference to the part played in the Durgapur project in India. They point out that they are in a position to offer a very complete service from the initial ore winning and processing to the manufacture of steel-finishing equipment. A further booklet reviews in picture form the activities of the companies, giving a fair example of the diversification of products and the substantial interest in the capital goods field. **Head Wrightson & Co. Ltd., Buckingham Gate, London, S.W.1.**

BCE 6971 for further information

About half the total of outbreaks of fire caused by friction occur outside buildings, often on storage sites and mainly involving chemicals and explosives, rubber and flammable liquids. A new Technical Information Sheet on the subject is entitled "Friction (Mechanical Heat and Sparks)" (No. 5004). **Fire Protection Association, 31-45 Gresham Street, London, E.C.2.**

BCE 6972 for further information

Squirrel - cage, totally - enclosed, fan-cooled a.c. motors are listed with dimensions and characteristics in a folder leaflet. These motors are of synchronous speed 1500 rpm, 3-phase, 50 cycle, 100/6600 volts (stock 400/440 volts), manufactured to B.S. 2083/1956. Accompanying it is a further folder setting out information on free space hydraulic couplings and drives. Every drive is guaranteed. They can be used with cheaper, smaller motors and starters, giving stallproof, cushioned drives and longer machinery life. They are available from stock up to 100 hp at 1450 rpm and are also available for powers up to 700 hp. **Crofts (Engineers) Ltd., Bradford, 3.**

BCE 6973 for further information

Chemical market research is a relatively new management tool which has grown up largely since the last war. It is based on examining who is buying the product or who will buy the product. What are the current markets and what will they be in the short and long-term future? What quality will be required; what size containers are indicated; what technical service will or would be required; what delivery schedules must be maintained? A brochure indicating the scope of their operations in this field is offered by **Roger Williams Technical & Economic Services Inc., Hanover Square, London, W.1.**

BCE 6974 for further information

"Soude Caustique" is a summary of the history of caustic soda and its methods of preparation. It gives tabulations of production figures, physical properties of the solid and of solutions and the forms in which the material is available on the market. A final section sets out in detail methods of analysis of the solid and of caustic solutions. **Solvay & Cie, Brussels, Belgium.**

BCE 6975 for further information

The KnitMesh Demister catalogue has recently been introduced, and gives details of the variety of products that can be manufactured from KnitMesh. **Knit-Mesh Ltd., 36 Victoria Street, London, S.W.1.**

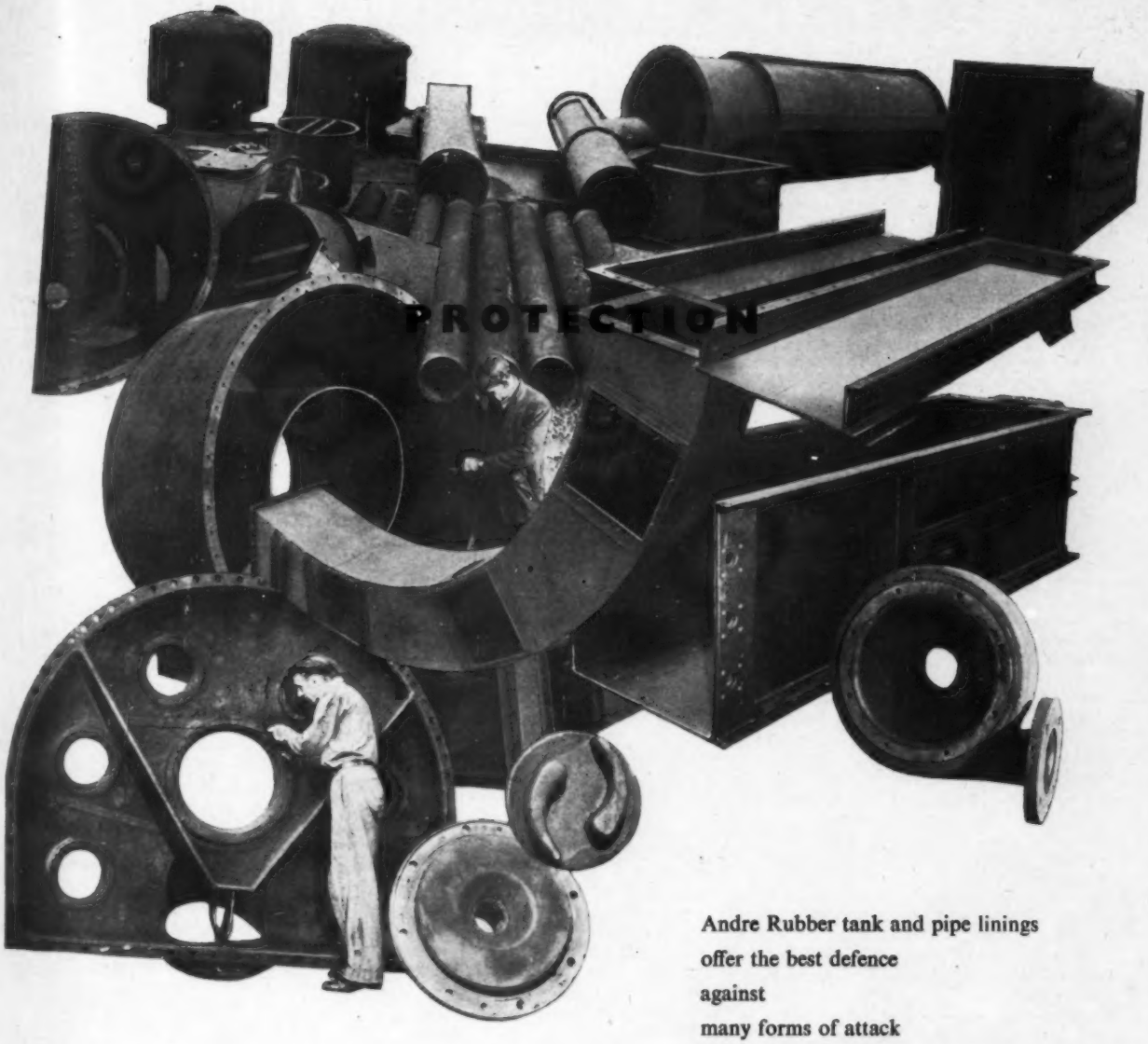
BCE 6976 for further information

Teleflex have sent us details of the various types of remote control gear which they manufacture. The field of industry covered by their controls is large and varied and ranges from window and ventilator controls to industrial equipment, such as boiler dampers and valves. There is also an Aircraft Division which manufactures equipment supplied to all the leading aircraft companies in Great Britain. Details of the company's most recent development, the Teleflex linear actuator, an electro-mechanical device designed for controlling very large dampers and valves, etc., with an output from 40 to 4000 lb., is also given. **Teleflex Products Ltd., Basildon, Essex.**

BCE 6977 for further information

Two new publications have been introduced by **Turner Brothers Asbestos Co. Ltd. P.O. Box No. 40, Rochdale.** One is a comprehensive brochure dealing with "Duraglas" glass-fibre products and the other is a booklet which details the company's complete range of P.T.F.E. products.

BCE 6978 for further information



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World of Chemical Engineering

New N. G. Plant

A new nitroglycerine plant with numerous novel features is now in operation at Ardeer. The new plant has been christened, for short, the N.A.B., and was evolved in the Gyttorp factory of Nitroglycerine Aktiebolaget, Sweden.

The N.A.B. system of injection nitration coupled with centrifugal separation is said to have simplicity and great safety. In the process the flow of nitrating acid through an injector sucks in the right amount of glycerine mixed with air. This injector system in which the vital reaction takes place is small enough to be carried in one hand. Less than a second elapses before glycerine is transformed to nitroglycerine, and this product immediately forms an emulsion with spent acid. In that form the product is safe.

After cooling the nitroglycerine is separated from the mixed acid in a centrifuge. This process occupies about half a minute and the nitroglycerine is passed to be washed free from all trace of acid.

With this combination of equipment the total amount of nitroglycerine in process during nitration and separation is only one-tenth part of the quantity in other continuous systems.

At Ardeer there is no moving machinery or free nitroglycerine in the nitrating house. Two centrifugal separators are situated in small over-mounded concrete block-houses, neither of which holds more than 15 lb. of nitroglycerine at any time when raw plant is in full production.

Nitration and separation processes are controlled from an instruments panel fixed to a thick reinforced concrete wall placed between the operator and the nitrating system.

Simple drills which occupy only a few minutes control the start-up or shut-down of the plant.

At present washing is being done by a column system also designed by the Swedish company, but Nobel Division research department work now in progress should yield a washing method that will match the simplicity and inherent safety of the nitration and separation stages.

When in full operation the new N.A.B. plant will have greater hourly output than existing units in Ardeer.

New Chemical Works

A new chemical works, to cost over £300,000, is to be built by Newton Chambers & Co. Ltd. on the site at Thorncliffe now occupied by Norfolk works and the Chemicals factory. A central laboratory block and an experimental workshop will be included in this redevelopment scheme. Clearing the site will begin early this year so that when actual construction of the buildings is started in April maximum advantage may be taken of the summer weather. Work will be carried out in two phases in order that the task of replacing the old works with the new ones shall be accomplished without interruption of production. In the first phase the main production section of the building will be completed by the end of 1960. Then during the first three months of 1961 plant and stocks will be moved to this section, which will at once begin operating as a unit while other work such as the demolition of remaining buildings is undertaken.

News Briefs

The trading operations of the Fison Group as and from January 1, 1960, will be conducted through the medium of subsidiary companies. The agricultural fertiliser business will be transferred to a subsidiary company, Fisons Fertilisers Ltd. The Horticultural Department will become Fisons Horticulture Ltd., a subsidiary of Fisons Fertilisers Ltd. Now that all operating and trading activities have been transferred to subsidiaries, the executive functions of the parent board will be exercised through two managing directors, Mr. J. W. Napier and Mr. A. Wormald. Fisons Horticulture Ltd., a new company which will be a wholly-owned subsidiary of Fisons Fertilisers Ltd., will have assets exceeding £1 million and will have as a wholly-owned subsidiary. Liquinure Sales Ltd., in operation since October 1, 1959, whose interests will be extended to the Benelux countries by the formation of Asef-Fison N.V. which will be an associate company operating from Utrecht, Holland.

Forth Chemicals Ltd., manufacturers of monomeric styrene at Grangemouth, Stirlingshire, have approved an expansion of their plant which will increase capacity to about 50,000 tons per annum in twelve months' time.

British Celanese Ltd. are to double the production capacity at Coventry for their polythene and other polyolefin monofilament and multifilament yarns. The first stage of the expansion was due for completion before the end of 1959 and it is planned that the new plant will be in full production by the middle of 1960.

A new process for precision fine grinding of a wide range of materials which was recently placed on the market in Great Britain is soon to be developed by W. Podmore & Sons Ltd. and Wm. Boulton Ltd., both of Stoke-on-Trent, and will be manufactured under licence in the United States by Southwestern Engineering Co. (SWECO), of Los Angeles, California.

Since September, 1954, the University of Sheffield has run two courses for executives in industry, commerce and the public service. These 12-week courses consisted of six residential sessions, each of a fortnight, held at one of the University Halls during six successive University vacations. The third course will take the same form and will be held in Stephenson Hall, Sheffield, beginning July, 1960; ending in April, 1962. The purpose of the course is to enable a group of men, selected by their firms or organisations as likely to rise to senior positions in business or administration, to widen and deepen their knowledge and understanding of social and business problems and the techniques available for their study. The mental stimulus of studies of this kind, assist to fit men better for greater responsibility, more receptive to new ideas and more flexible and resourceful in their outlook. Full details from Professor D. C. Hague, Department of Economics, The University, Sheffield, 10. Telephone 27451.

Overseas News

Komplex Trading Co., of Budapest, has bought complete equipments for two caustic soda plants from Krebs Cie. of Paris. One of the plants is to be installed at the Hungaria Chemical Works, Budapest, while the other will go to Berente in north-east Hungary. The annual capacity of each caustic soda plant is 10,000 tons approximately. The value of the plants is about $2 million.

The world's largest plant for the direct reduction of iron ore to sponge iron is taking shape in Monterrey, Mexico. The plant will use the new HyL process to reduce iron ore by direct contact with hot, re-formed natural gas in batch-type reactors to produce 500 tons per day of sponge iron. It is designed and being built in Monterrey by The M. W. Kellogg Co., New York, for Fierro Esponja, an affiliate of Hojalata y Lamina, one of Mexico's leading steel producers.

In the accompanying photograph five Kellogg gas re-forming furnaces are shown on the left almost completed. The large-diameter pipe in the foreground will carry the re-formed reducing gas from the furnaces to the reactors, centre and right background. Iron ore will be charged to the reactors and reduced by the gas to a high-quality sponge

The world's largest plant for the manufacture of sponge iron being built by Kellogs for HyL affiliate Fiero Esponja at Monterrey, Mexico.

BCE 6894 for further information

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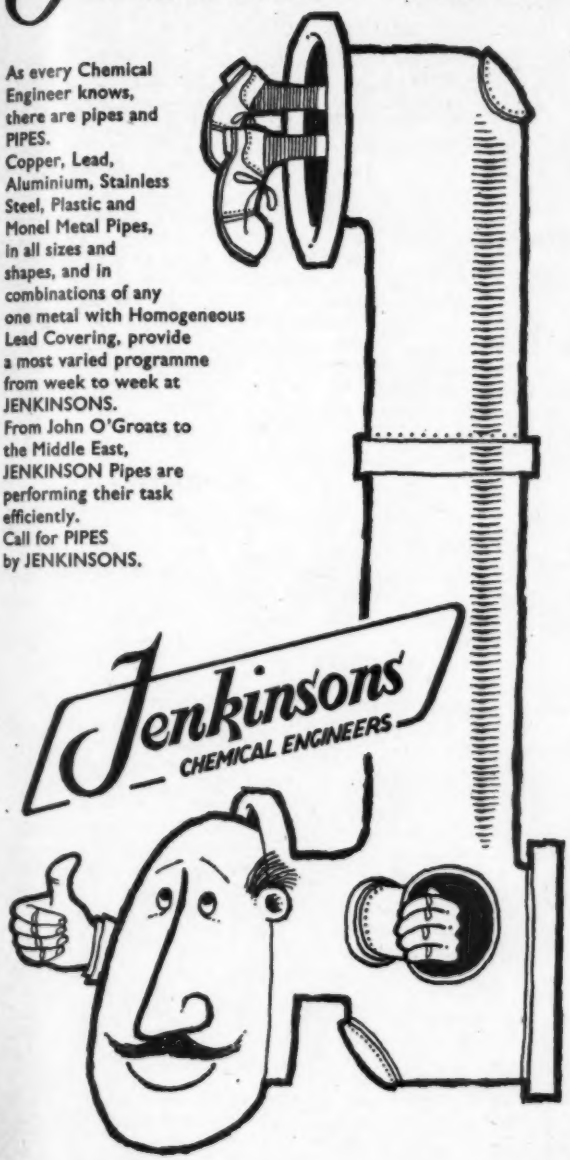

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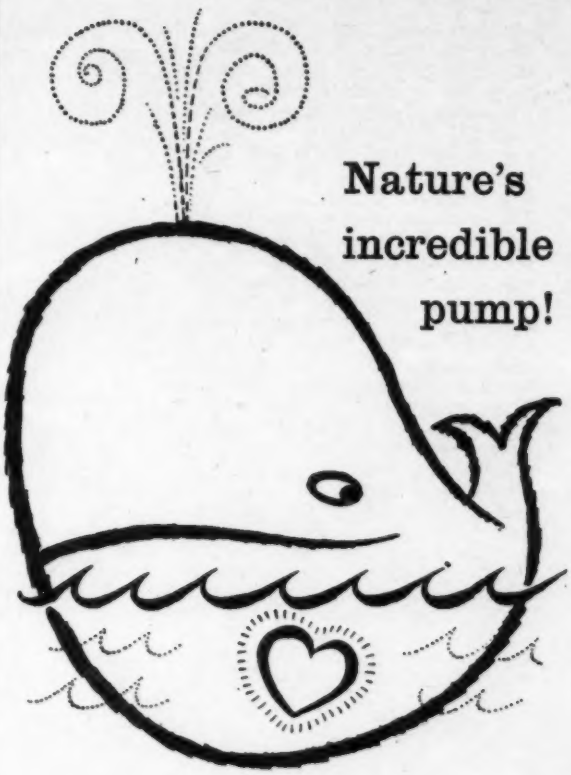

Nature's pump is the heart; and the biggest heart belongs to the Blue Whale. A 90 ft. specimen has a heart weighing half a ton—big enough for a boy to crawl into (which is exactly what a boy did, many years ago). We do not make Metering Pumps as heavy as that, but size is no criterion of a a Metering Pump's efficiency. It would be better to judge our Metering Pumps by the way in which they handle almost anything from concentrated sulphuric acid to plain water—in quantities up to 1200 g.p.h. and at pressures up to 5000 p.s.i. as standard. We are always interested in considering special features to suit site conditions or process problems. (If you have such a problem at this moment, put it in a letter to us immediately). And note this, too. Our After-Sales service is geared to serve you in every possible way.

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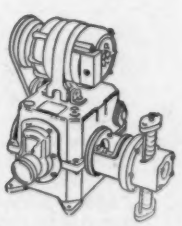

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iron. The sponge iron will be charged directly to electric furnaces and converted to steel. The new plant is scheduled for production in early 1960.

Consolidated Mining & Smelting Co., controlled by Canadian Pacific Railway, have started construction at Trail, British Columbia, of a $2.6 million alkali chlorine plant.

A new route to acrylonitrile has been developed in the Sohio Research Centre in Cleveland. Sohio Chemical Co., a wholly-owned subsidiary of Ohio Standard, is already building the first commercial plant to use the new process. Location is at Lima, Ohio. The plant is scheduled to go on stream early in 1960. Basically, the Sohio process is a catalytic vapour-phase, one-step reaction. The operation is conducted at moderate temperatures (below 900°F) and low pressure (less than 3 atm.) with a residence time of only a few seconds. It is said to be highly selective and to give good yields of acrylonitrile and commercially recoverable amounts of valuable by-products — acetonitrile and hydrogen cyanide.

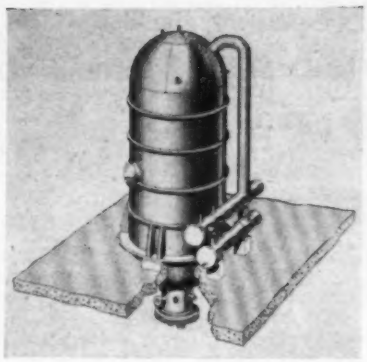
The Uddeholm Co., steel and forest combine in Central Sweden, has recently put into use a large plant for the production of trichlorethylene (TRI)) and perchlorethylene at its Skoghall works. It has a capacity sufficient to cover Sweden's needs of these cleaning media, in addition to permitting of a sizeable export. The plant is fully automatic.

The formation of a new company, Deutsche Dow Chemie G.m.b.H., with corporate seat in Düsseldorf, Germany, has been announced by Dow Chemical International Ltd. S.A. The wholly-owned German subsidiary will provide German operators of oil and gas wells with acidising, fracturing and cementing services. It is assumed that the principal office of the new company will be in the Hanover area with some service points to be established later. The initial paid-in capital of the new corporation is 5 million DM ($1.25 million).

On Tuesday, December 29, 1959, the President of India, Dr. Prasad, commissioned the first blast furnace at the Durgapur Steelworks, West Bengal. The Durgapur Steelworks represents the largest single export order ever obtained by Great Britain, and is valued at £105 million. The work is being carried out for Hindustan Steel Ltd. by the Indian Steelworks Construction Co. Ltd., ISCON, the consortium formed specially for the purpose.

The ceremony on December 29 celebrated the inauguration of an integrated steelworks and not just the completion of one blast furnace. The coke ovens are complete with a coal washery, and by-products plant. The blast furnace is complete with a gas cleaning plant and pig casting machine. The power plant is complete with all its standby units. In addition, the central engineering maintenance department, foundry and stores department are very largely complete.

Something new in evaporator design and construction, said to solve tricky problems in concentrating radioactive wastes which Consolidated Edison Co. of New York Inc. must dispose of when its new 275,000-kW Indian Point nuclear power plant on the Hudson goes into service in April, 1961, has been designed by Chicago Bridge & Iron Co. The evaporator will be made entirely of Inconel (nickel alloy), and have an entrainment section of woven stainless steel six times the usual thickness. The design calls for a welded flangeless unit. The unit will accept wash-down and purge water from the entire plant (reactor area, laboratory, laundry and filter backwash operations) and vaporise it so effectively that less than five parts in 100 million of dissolved solids are in the discharge. An ion-exchange unit will cut this minuscule amount to less than one part in 100 million, as safe as the Hudson River.



This all-Inconel evaporator, measuring 19 ft in height by 6½ ft in diameter, was designed by C.B. & I. to concentrate radioactive wastes generated at Indian Point nuclear power plant.

The evaporator, engineered for a 6000 lb./hr boil-off, measures only 19 ft in height by 6½ ft in diameter, and has hairpin steam heating loops which may be cleaned by thermal shock. The mesh demister (entrainment separator) will be 3 full feet thick (4 to 6 in. being the most generally used in refinery practice), and every vessel weld will be completely inspected radiographically. The unit has been rated by Consolidated Edison as a primary vessel because the evaporator will handle water which has been used in the primary loop of the reactor steam generating plant. The unit concentrates all material requiring evaporation that leaves the plant. It operates on steam at 250 psi max. and will never have to sustain internal pressure over 50 psi.

Contracts

George Wimpey & Co. Ltd. are engaged on the design and procurement for a large chemical plant, including gas cracking and polyethylene plants, to be erected at Antwerp, Belgium, for Cobenam S.A. The estimated cost of the project is about £4 million.

P.G. Engineering Ltd., Stockton-on-Tees, has received instructions from the North Eastern Gas Board to build a plant, at the Whitby Gasworks, to re-form natural gas. The installation is said to be the first of its kind for this application in this country. The plant is due for completion by July, 1960.

Sharples Process Engineers Ltd., London, are to supply to Roumania two complete edible oil refining plants—one for a Bucharest factory and the other for a factory in the provinces. The plants will be designed for continuous operation, with automatic control, and will be the first of their kind in Roumania. The two projects together are valued at about £½ million.

Birwelco Ltd., of Aston, Birmingham, announce that they have been awarded the contract for the supply of seven Petro-Chem Iso-Flow furnaces for the new Esso Refinery on Milford Haven. The total value of the order is more than £300,000.

John Thompson Water Tube Boilers Co., of Wolverhampton, have received from the Central Electricity Generating Board a letter of intent to place a contract valued at approximately £6 million. Under the contract, John Thompson will supply two water tube boilers and their accessories for two 350-MW units at the Drakelow "C" power station in Derbyshire. The boilers, among the largest single units yet ordered by C.E.G.B., will be coal fired.

Obituary

We regret to announce the death at 45 of **William E. Dick**, the first Editor of *British Chemical Engineering*. Educated at King's College School, Wimbledon, Mr. Dick studied biology at Imperial College, London, and obtained a second-class Special Degree in botany at Chelsea Polytechnic. He was a Fellow of the Linnaen Society. Mr. Dick saw war service with the Royal Army Service Corps, being attached to a camouflage unit, but was invalided out shortly after Dunkirk. Still determined to play some part in the war, however, he joined the Auxiliary Fire Service.

His career in journalism was typically characteristic of the man, as he brought the whole of his energies to making whatever journal he was engaged upon the best in its particular field. Perhaps one of the best examples of this was his undoubted transformation of the journal *Discovery* from a little-known and read publication to a world-wide, renowned scientific paper which in his ten years of editorship came to be looked upon as the epitome of how best to present serious and advanced scientific papers in a light and easily assimilated form. In this sense he was unrivalled in his journalistic craftsmanship.

As the first Editor of *British Chemical Engineering*, Mr. Dick nursed this journal through its most difficult period, and saw it firmly established before leaving to take up the position of Editor of *Chemistry and Industry*, the weekly journal of the Society of Chemistry and Industry. To this new task, Mr. Dick brought once more his sense of fitness for matters scientific, ably balanced with articles on events of note in his new journal's field. *Chemistry and Industry* soon showed in its pages the sure touch of its new Editor, and Bill Dick could have no more fitting epitaph than this journal—nor, knowing the man, would he have asked for more.